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Year Book of the Society ..... Vol. 1, No. 5, Pages 1 to 91

EDITORIAL

EDITORIAL FOR TRANSACTION OF AMERICAN SOCIETY FOR STEEL TREATING

Greetings are extended to all of the great fraternity interested in steel treating, and especially to those who are members of The American Society for Steel Treating. The society had a most auspicious start at its convention and exhibition in Philadelphia, as all of you who were enabled to be at the meetings know. The booths were well arranged and very well patronized. The meetings were especially well attended and the papers heard with much interest.

It is hoped that the membership committees in our various chapters will be especially active these next few months in building up the membership. This suggestion is made not from the angle of seeking increased membership, but because it is believed the society has a message to extend to all the many thousands interested in heat treatment, and an increased membership is a most effective means for transmitting this message. It is suggested that an attempt be made to make the membership well rounded. Interest in the society should be created from among heat treatment shop foremen, plant superintendents, laboratory technicians, etc. No one is in too humble a position, nor no one in too high a post, provided there is the basic desire or need for information in this field, to debar him from membership in the society. It will only be with a well rounded membership that the society can grow. The creation of interest from all classes in this one field will be of great value to the individuals, will insure live meetings, and will be of broad benefit to the profession as a whole.

A. E. WHITE, President.

The 1920 convention and exhibition of the American Society for Steel Treating is now a memory. But such a remembrance! The magnitude of the exhibition, the success of the meetings, the remarkable quality of the papers presented, the large and enthusiastic attendance, all these and many more important incidents and events combine to reflect credit upon the young and rapidly growing society.

May the efforts of the members continue in the channel of progress and thus may each convention and exhibition set an increased standard of excellency, a higher goal towards which to aim and strive.

THE CONVENTION

Opening Session of the Second Annual Convention of the American Society for Steel Treating was called to order at the Commercial Museum, Philadelphia, Pa., September 14, at 10 a. m., by Chairman A. E. White of the Amalgamation Committee.

CHAIRMAN: I know that it is with great pleasure that all of us are able to be here in this room this morning, at what is substantially the Second Annual Meeting of these Steel Treating Societies, which, in but a few moments, will become one society.

We are indeed fortunate this morning in having with us the direct representative of Mayor Moore of Philadelphia, who tells me that he has represented seven Mayors of Philadelphia. I wish you could have all heard the wonderfully complimentary remarks made with regard to him by a real Philadelphian when he told me that Dr. Cottrell has spoken to

over two million people, he has heard him six times on substantially the same subject, and could hear him six times more and at each time with greater interest It is with great pleasure indeed that we are able to turn this meeting over for a few moments to Dr. Cottrell, who will represent the City of Philadelphia and formally welcome this society to this city.

DR. COTTRELL: Mr. President, Officers of the Association—Gentlemen: I am very happy to be here, although I do regret that His Honor Mayor Moore, being out of town, is unable to give in person the official welcome of the City of Philadelphia. He is very much disappointed, and he asked me to convey to you that sentiment. You have the keys to the City, and we beg to say you are doubly welcome. We are very happy to have you here and very proud to have you meet here in Philadelphia. I am very happy, out of this misfortune, to have this opportunity to look into your faces and bid you God speed. It has been my privilege to be associated with seven of our Mayors, taking in nearly a quarter of a century, and to have been associated with the building up of this commercial Museum. This was the first movement under President McKinley to develop foreign trade here in 1893. They have the records here of over 350 thousand foreign firms all over the world. In this very building we held in 1899 the Congress of Commerce, with delegates from every country in the world. It cost the city about $150,000 to take care of that convention, but it was the mother or the beginning of that great foreign trade which I feel is the hope of the whole world, and on nothing else is that trade so dependent, in my mind, as upon the steel industry. You are the kings of the future. I find in fifty years of clear-cut memories—I have known every President since Abraham Lincoln—I have written about 85 separate organized governments, spending about 25 years in travel all over the world, studying our own government and contrasting it with other governments—last year it was my privilege to look into the faces of 1,100 different audiences—I believe my total in the last 17 years runs up to seventeen million people. I mention those facts to give force to my words that I have at this moment a stronger faith in our form of government than I ever had at any other period in my life, and I am more optimistic about the future than I ever was at any other period of my life. (Applause.)

Some 500 or 600 of those meetings last year were meetings where organized labor was prominent, and I said in New London recently, speaking to the New England Bankers from all over New England—and I said again in Buffalo and in Cleveland, that from my knowledge of labor I believe 97 per cent of the labor of America was bomb-proof against Bolshevism, because the home life is the basis of our real life, and Bolshevism is founded on the principle and determination to destroy the home.

As for trained leaders, you take the work of our universities and take the work of our great shops and wherever I go I find a more indulgent direction and a heartier cooperation between the individual workers and the leaders.

I was so struck recently by a trade publication account of one of our big manufacturing establishments here and the get-together spirit they showed that I sat down and wrote them a letter from the Mayor's office, congratulating them and saying how it put new heart into me in going about the country and trying to say some good words about Philadelphia. They printed my letter in full, photographed in their house paper. I talked to two thousand foremen not long ago, and I was struck with the

wonderful level of intelligence that was everywhere shown in looking over that sea of faces, and the family spirit, the cooperative spirit that seemed to be developed.

Let's take our courage in both hands and regard this meeting that gives you a chance to prove that "sovereign and Divine right" is not a grace alone; that in this crisis of the world, when the whole world is leaning on America, that each one of us has responsibilities we must live up to, and that, living up to them, there is no doubt about what the result will be in our ability to help America lead the world back to paths of pleasure and peace.

It is delightful to come out in the early morning and face a body of men like this—so different than the question which the little boy asked of his mother, "Mother, where does the light go when it goes out?" And she replied, "That is a foolish question, you might just as well ask me where your father goes." You are all alike; you are men, and know life and enjoy it. Thank God for life. That is the prayer of my life. I have lived a good many years. I have had a good deal of fun. I have known both ends of the string. I have lived on $500 a year and spent $25,000, and I have been equally happy in both conditions. I have been all over the world; I have been thousands of miles from here where I didn't know anybody, and I have been where I had friends all around me—we have that touch of Divinity that if we will only feel it gives us power to stand squarely on our feet. If we get a blow, go to the grass, wipe the blood off and get into the race again and fight and win. "He who wrestles with me strengthens."

Now a good many of us have had to take that kick in the face before we learned a lesson. I believe that by organization, by consolidation of organizations, you are getting into a position where you are able to avoid that kick, and learn in a pleasanter way the great lessons of life we have all got to learn if we are going to live and let the other people live. Don't be afraid of getting old. I want to live to be 100 years old, and then renew the lease and double the rent and do my own repairing, and keep the furniture—you never see cheap furniture with a marble top. (Laughter.) You can always get a bright slant if you want it. Even the prohibition act has a silver lining; when your wife kisses you when you come home now it is a kiss of affection, not of investigation. Try to find the bright side. Pessimism and paralysis are synonyms. A pessimist is a blind man in a dark room looking for a black cat that is not there; a fellow who don't amount to anything and would lick his child for growing. Take the other slant of it. Be like a little chap that fell down stairs in one of our public buildings and when I picked him up he said, "That's all right, Mister, I was coming down anyway."

I am very glad to welcome you on behalf of the Chief Magistrate of Philadelphia, the 109th of this City. We were founded in 1683 so we have a long list of over 225 years back of us. We began with certain principles laid down by William Penn which the whole world is adopting today. If you will take the latest Bankruptcy Act, if you will take the latest act on foods and drugs, those acts which endorsed honesty and fair dealing, I will show you sentence after sentence that is verbatim from letters written by William Penn—"Irrespective of the ability or disability to judge measurement the exact quality and quantity bargained for must be delivered." All provisions in those early days were made to prevent debtors escaping. There are a thousand and one things in the original plans for the City of Philadelphia, for the City Beautiful, that are being

carried out today in other cities all over this country. We were to have trees on every street and trees between every house. There was to be an orchard attached to each home so the children could see nature in her productive mood. All these modern improvements were born in that old day, because Penn was a courtier before he was a Quaker. He was associated with all the brilliant men of the Continent in his day and when he came over here he laid down just one rule—that was that a man must believe in a God, but after that it was left free. He couldn't understand the brotherhood of man unless you have the Fatherhood of God. So we started with the idea that thrift also was a virtue, and, beginning early in Pennsylvania, we have been able to pass on to each generation enough capital to handle their new development so we stand today with fewer outside debts I believe than any other community in the world. It is only within about four years that we began issuing our first bonds in the State of Pennsylvania, and they are to build roads. Our debt here doesn't represent more than one-half the value of our assets in Philadelphia, because we have been limited under the Constitution for years, until two years ago, to making a loan which must be paid in thirty years. We have tried to develop the home life here because we believe that home life is the basis of all happiness and contentment; because we believe in the home you can teach a lesson that cannot be taught anywhere else; because in the home the child obeys a law, not because it understands the law, but because it has love for, and confidence in, the law-giver. The trouble today is that every man wants to interpret a law according to his way and his views, and there is a very widespread tendency to break a law we don't like, and obey a law we do. I heard some men at the club boasting about how they were getting about the Anti-liquor law. They didn't like it. I said to one of those men, "I take no position on that question—I have used the spirits for many years, but don't forget this: You have property that is protected by law. You have a splendid auto protected by law; here is a man who don't believe you ought to have an automobile; he don't like the law that lets you wear a diamond pin and carry a watch or carry money in your pocket, and he breaks that law and takes your watch and assaults you and takes your automobile: you don't like the Prohibition law, and you break it. You each occupy in law exactly the same position, and if our government is to continue—because it rests on the law-abiding spirit—any man who breaks any law is giving license to another man to break any other law; that is the principle we have got to consider, because under our form of government it is voluntary law-abiding from within rather than compulsion to obey a law from without." Last night we guarded in this city 435,000 buildings scattered along 1,750 miles of streets, with 1,000 men, because nine out of every ten men are law-abiding, and law-respecting in America. Had we been under an autocratic government such as the old Russian Government, it would have taken 25,000 men to enforce obedience to law, where the 1,000 men was sufficient here. Now under our form of government the difference between the expense of 25,000 law enforcers and 1,000 gives us a fund out of which we spend two and one-half million dollars a day for education, and two and one-half million in supporting the great moral agencies. Every time the man obeys the law voluntarily he relieves the state of a certain amount of expense and leaves a larger sum to build the things that build character and so buttress the foundations of our great Republic. We have in the City today 390,000 separate dwellings. You will notice the tracks with the

trolley car going by. That is one of a family that today will go ten times around the earth without going out of Philadelphia. The total mileage of all the cars in Philadelphia will run about 240,000. If you wanted to make a call at each of our homes, it would take you twelve years. You could go through our water pipes from here to St. Paul and down to Omaha. In normal times when we are running on our usual schedule, occupying our 350,000 army of skilled labor, we turn out every second 25 pairs of stockings; every second we make a new saw; every two seconds we make a new hat; every three seconds we make a new pair of lace curtains; we build a trolley every hour, a locomotive every two hours. In normal times we build a new home every twenty minutes and a new baby every thirteen. (Laughter.)

And in that connection I once heard of a strange thing that happened. I was down in North Carolina, and I said to one of the men there, "You have a remarkable increase in births here, how did it happen?" "Well," he said, "the Southern Railroad put on a new train that went through here at 4:00 o'clock in the morning and woke everybody up." (Laughter.)

Along that line, my dear old father helped to bring Texas into the Union, and to take it away from Mexico. About 25 years before he died he went down to revisit some of the old towns he knew and about a few years before he died I revisited the same towns. In talking with the old hotel proprietor I said, "My friend, how many people have you now?" "About 4,800," he said. "You mean 48,000, don't you?" I asked him. "When we were here twenty years ago you had that many, and the nation has grown nearly forty million." "Well," he said, "that was exactly the count according to the census that was taken not long ago." I said, "That is strange; have you any theory? Has the birth rate kept up?" "Yes," he said, "the birth rate has kept up all right, I guess; about the only way I can account for it is that every time a baby is born some fellow has to leave town." (Laughter.)

You see they broke even. And there are a great many people in the business and other lines that are doing a tremendous business at the front door and losing it at the back, either through lack of education and intelligence or through lack of the moral qualities. We have to be sure that we both understand the word "straight" to mean the same thing. Out in Cleveland not long ago they arrested a Darkey for selling stewed rabbit adulterated with horse meat. They asked him how he adulterated it and he said, "Well, I did it on the 50-50 basis, one horse to one rabbit." (Laughter.) Don't let's jump at the idea that the other fellow believes as we do. I want to welcome you on behalf of the City Chamber of Commerce, also. We have, I believe, the largest membership in that body of any similar body in America, over eight thousand now. All the great agencies are working together to make the old mother city renew her youth and be able to live up to the traditions of the past. I bid you welcome in their name as well as the name of the city. I ask you to forget the technical side of your meeting while you are here, get out of the rut that we all get into for a little while, get a little to yourself and go down for just a little while to that old Independence Hall and stand for a few momens and listen to the message which that old bell will give to you, individually. I have now nearly 59 years of memories of that bell. An early memory was the day when Lincoln lifted the flag in '61. He was little honored then; didn't even have a guard; he was going down to Washington to be inaugurated.

Then I remember in '65 being in the room after standing all night in

Independence Square, after God had called Lincoln home, and in the early dawn going into the old room that the Declaration was signed in and looking at the face which seemed already to my eye to hold the light of Eternal morning. I was there two years ago with a college professor and he sat on the rostrum where the Presiding Officer at the Constitutional Convention sat years ago, and that college professor today is the President of a mighty institution.

In the same building I attended three or four great conferences, and out of those conferences have grown Independent nations that exist today. The old mother city in that old cradle which rocked our new nation into being has rocked other nations, and we are the foster mother.

But one memory I have that I hope God will let me have to the last, and that is when I took a young sailor there one night during the war. I had been down there to see that the bell was tolled at 9 in the evening. We were having certain general observances here, and as I came back an officer was having a dispute with a big sailor, a fellow about 24 years old, standing about six feet two. I went up to see what was the trouble and the officer said, "Dr. Cottrell, this boy wants to go in to see the Liberty Bell, and I told him that the place is closed, but he won't take my word for it and wants to go anyway; you tell him that he can't see the bell tonight." I said, "My dear fellow, the officer is telling the truth; come down in the morning and I will be delighted to take you in. You are answering the call of that bell." He said, "I can't do it; I have just gotten into Philadelphia at 6:00 o'clock tonight; I have never been in Philadelphia before, but my mother was born in Philadelphia; all her life we lived in Milwaukee, and all her life she used to talk about that Bell and her Bible. Last February God took father from me, and my mother and myself have been more like brother and sister since then. Then the mother went away, and I was left alone. I went into the Navy because I thought I would be nearer the mother fighting, but I would like to see that bell; it would bring her back I think for a moment and give me a new grip." I said, "My boy, you are going to see that Bell." I took him around to the Wall Street side and knocked on the door. The watchman was just finishing his hourly inspection of the tower. I said to him, "You know I represent the Mayor and I am going to take authority here for a moment; I won't violate any of your provisions; enough light comes from the lamp post in the square by the Barry Statue." I led the man into the vestibule. The Bell was then nearer the door than it is today. It was very dark in there, but I could see the bell and I put his hand on it. Then I stepped into the shadow, thinking I could open the window so it would let in a little light. When I turned to come back—of course I was concealed in the shadow—and I was sorry for a moment I was there, because the boy, thinking himself alone, had dropped on his knees in front of the bell, and as I watched him with his face silhouetted with the light from the square I saw his face lower until his lips touched the Bell. Then I heard him say, alone in the darkness, "God help me to make good." That big boy was nearer the mother he had loved and lost at that moment than he will ever be again until he meets her. That is the spirit that our boys had, all of them. That was the spirit which animated the seventy thousand Americans who sleep today over seas, and every one of those seventy thousand Americans that are sleeping over there signed a bond with his life blood which you and I have got to sign and keep to be bigger and better Americans in the days that are to come than we have ever

been in the past. We have got to make Old Glory mean more. We have just listened to. It would be a case of anti-climax, and it would be recognize that the world don't owe me a living; I owe the world a life; by playing the game straight as well as strong, recognizing that we are "sovereigns of Divine Right," touched with the Quickening Finger of the Living God; we have got to carry this country through any crisis and to make America the hope of the whole world.

May God bless your deliberations, make you better citizens, make you more able to hold Old Glory aloft where it ought to be the hope of mankind. (Prolonged Applause.)

CHAIRMAN: I am sure that we feel we owe the City of Philadelphia a debt for sending to us Dr. Cottrell to welcome us officially to this glorious old city. We all know of Philadelphia as the "City of Brotherly Love," and I think all of us in this society feel exceptionally fortunate in being able to come here and hold our annual convention and our annual exhibition. It would not be fitting for me to attempt to make any response at this time to such a splendid address and such a wonderful tribute as we have just listened to. It would be a case of anti-climax, and it would be better not to say anything than to have a condition like that.

I think, however, that it is exceptionally fortunate that we are here. I couldn't help feeling last night just before I went to sleep how fitting it was that we assemble here in Philadelphia. Philadelphia, as we know, was the city in which our forefathers gathered and prepared the Declaration of Independence. It was not the first time that the Continental Congress met, but it was the first time that Continental Congress welded hands together so that this nation might rise and become the power for good and the uplifting of humanity that it is today, so I hope that at this time, although it is not the first time that either one of the societies that are becoming amalgamated have met, yet it is the first time that they are meeting in a spirit of union, and as the Declaration of Independence rang out that spirit of Liberty and power and strength, so I hope that at this convention it will be the start of what is already a vigorous and strong society, but which we hope from now on will become bigger and stronger and better and more resultant of the things for which our society stands.

Again I wish to thank Dr. Cottrell, representing the City of Philadelphia, for being with us this morning.

DR. COTTRELL: I am very happy indeed to have been with you, gentlemen.

CHAIRMAN: Our next order of business is the appointment of the tellers, and in that connection I appoint Mr. Collins of the Philadelphia Chapter, Mr. McCloud of the Detroit Chapter, and Mr. Smith of our Indianapolis Chapter.

CHAIRMAN: I think it is highly appropriate at this time just preceding by a few minutes the formal announcement of the amalgamation of the two societies, that we have an Annual Report from the Presidents of Both Societies, and I will therefore at this time ask Professor John F. Keller, President of the Steel Treating Research Society, for the report of the Steel Treating Research Society. (Applause.)

PROF. KELLER: Gentlemen, fellow members of the Steel Treating Research Society, members of the American Steel Treaters' Society—I am glad to be with you today. This report, however, has been prepared for the members of the Steel Treating Research Society. There are some few notes on the American Steel Treaters' Society.

REPORT OF JOHN F. KELLER, PRESIDENT STEEL TREATING RESEARCH SOCIETY

It affords me great pleasure indeed, to present to you, a final report of the splendid progress and activities of this, the first scoiety of its kind organized in this country. The object of which was to furnish information to the practical Heat-Treater, through the presentation of papers and discussions of the various phases of their work—eventually to bring about a closer relationship, between the graduate Metallurgist and the practical Heat-treater, hoping thereby to combine theory with the practical knowledge of men; who, in many cases devoted the greatest portion of their lives to the manipulation of Iron and Steel.

It was to the vision and foresight of a practical Heat-treater that we are everlastingly indebted for the foundation of this splendid gathering here today.

It was to this man, who had risen from the trade of a Blacksmith and practical Heat-treater, to that of a service man for a large Steel Producing Company, whose duty it was to furnish information and demonstrate proper methods of treating Steel to Foremen of such departments.

In his daily vocation, he soon discovered the limitation of the average workman and their willingness to accept advice. From this, he conceived the idea of bringing together a number of men interested in their work. The first gathering from which this Society grew met in the year 1913, at the Fellow Craft Club, and consisted of eighteen Heat-treating Foremen. The meeting was so successful from a social and educational point of view that after a few such meetings, it was suggested that a Steel Treating Society be formed and that the gathering be held regularly each month. This was unanimously adopted and the Society was formed. Mr. Lawson of the Cadillac Motor Company was elected as the first President for the year 1914.

The growth and expansion from this humble gathering of practical Steel Treaters is past history, but great credit must be given to the man who conceived and assisted in building the foundation of this great Society. The gentleman is none other than our esteemed fellow co-worker and past President of the Steel Treating Research Society, Mr. W. P. Woodside, a man who is deserving of the sincere thanks and appreciation of every member of this Society, and in fact from all future members, for his unselfish efforts in promoting an organization of educational value to practical Heat-treaters, and which made possible the Society of today.

In reporting the splendid progress of our Society during the past year, I feel that you are entitled to an apology for my apparent indifference to the active official business of the Society; but I wish to assure you that although business required very close application nearly all of my time, this very fact enabled me to further the progress and interest of the Society through close personal contact with industrial employes over a widespread section of the country. Also as regards my not maintaining actual control of the business of the Society in my absence, it was being taken care of by our very accommodating and enthusiastic Vice-President, Mr. L. A. Danse, and efficient Secretary-Treasurer, Mr. L. S. Carrick, for which valuable assistance I sincerely thank them.

My greatest desire and ambition, however, was to bring about a more cordial relationship between the officers and members of the two great Steel Treating Societies. With this in view as the main objective, I decided to put forth every possible effort to create a more fraternal

feeling between the opposing factions, and if possible, to assist in uniting the entire membership of both Societies into one harmonious organization.

In my humble efforts to bring about this desirable condition of affairs, I am very glad to report that I found a fertile field indeed, for action. The universal opinion among the majority of the members of both Societies was for a consolidation on the popular grounds that there was not room for two Societies functioning along the same line of endeavor. With this general feeling and desire as an excellent foundation to work upon, the next step was to approach the representative of the other Society with that fraternal feeling of, "Brother, I will meet you half way for the good of the greatest number." I am pleased to report that the fraternal feeling was reciprocated in spirit as well as in action. The splendid co-operation of the national officers of both Societies in this matter is a series of interesting and profitable meetings that I shall always remember with pleasure. The commendable, loyal and untiring effort of the various committees appointed deserve exceptional praise for the laborious tasks so well performed.

With this combination of unselfish efforts and good will of all concerned, the culmination of our desire and ambition was gloriously achieved when the voting power of the national officers and members decided by unanimous vote to amalgamate under the banner of the American Society for Steel Treating.

In the achievement of our objective and desire for the above amalgamation there is one man who must be given entire credit for its success. It was through his untiring and unselfish efforts as a neutral that the first meeting was arranged at Battle Creek, Michigan, September 2, 1919, at which meeting a committee was appointed to prepare a tentative constitution and plan of action for approval and recommendation of the officers of both Societies. From his concentrated efforts at this meeting and all others the superstructure of the American Society for Steel Treating was outlined, constructed and cemented together. The finishing touches to his ideal structure created for the benefit of the Steel Treaters of the country will be completed when the first convention of the American Society for Steel Treating is called to order this week. The foundation of his ideal, however, has only begun, for he anticipates making the American Society for Steel Treating one of the most successful and useful organizations of its kind to the manufacturers and users of Steel in the country, if not in the world. Gentlemen, I refer to Professor A. E. White, National President of our new Society. I assure you he is deserving of the heartfelt thanks of every officer and member for his unselfish efforts and his loyal devotion for the good of all concerned.

There is one other gentleman that deserves our thanks and appreciation for the culmination of efforts toward the amalgamation of our Societies. I refer to Mr. T. E. Barker, President, American Steel Treaters Society. In all my consultations and associations with Mr. Barker in committee work and otherwise I found him a perfect gentleman, a conscientious official, extremely loyal to his organization, but always willing to concede a point where it would do the most good for the greatest number, and a man who is deeply interested in the personal and educational welfare of the Steel Treaters of the country. I take this method of thanking Mr. Barker for his courteous treatment and his untiring efforts toward the complete and successful amalgamation of the two Societies. I also wish to congratulate the Nominating Committee for selecting Mr. Barker as Vice-President of our new organization.

This part of the report would not be complete without expressing our appreciation and thanks to the members of the Amalgamation Committee for their prompt attention to the strenuous task of developing the remarkable constitution submitted for ratification.

Personally, I have been unable to take a very prominent part in the various activities of our Society or the amalgamation proceedings. However, I have visited the following Sections, Chapters and Societies for the purpose in most cases of delivering a talk and demonstration on "Steel, Its Selection and Treatment," as follows:

The Fellow-Craft Club, of Flint, Michigan, our Indianapolis Section, The Cincinnati Chapter of the American Steel Treaters Society, an open meeting of the Steel Treaters of Toledo, Ohio, which was finally organized as a section of our Society; the organization meeting of the South Bend Section, the Rockford Engineering Society, of Rockford, Illinois, and the Chicago Chapter of American Steel Treaters.

In conclusion, gentlemen, I want to personally thank all of the members for the splendid cooperation that has been given me in my work. I also want to thank our members for the splendid effort and their splendid cooperation towards the successful amalgamation of this society. You have the combined membership of both societies represented among the new officers, and you have selected excellent officers, men who, from my personal experience, association, and working with, I believe will develop a society of considerable strength. They will lay down laws which have already been laid down; they will make an effort to develop this society, but I say to you members, these men cannot do much in their efforts unless they have the combined cooperation of each and every member of the organization.

CHAIRMAN: At this time I want to call the attention of all here to the very excellent program of papers which the program committee have been able to secure. It was my good fortune yesterday afternoon to be able to casually look them over, and I was surprised and pleased to note the excellent character of every one of the papers. Our Program Committee is to be congratulated in getting the papers and in the care with which they have been selected. I feel that none of you men can afford to miss the papers which are presented here.

It is with great pleasure that at this time we can call upon Mr. T. E. Barker, the President of the American Steel Treater's Society, for his Annual Report.

PRESIDENT BARKER: Mr. Chairman, Officers, Delegates and Members of the American Steel Treaters Society and the Steel Treating Research Society; it is true, as our Chairman says, that my name is Barker, but I want you to know that I am very sensitive about being mistaken for one of the Mexican Hairless variety. I might elucidate upon that a little by relating a little story that I ran onto a few days ago. I don't recall just what it was, possibly the Ladies' Home Journal, but O'Brien's over-educated daughters were endeavoring to bring up father, who had made a large fortune as an excavating contractor, by inveighling him into refined society at every opportunity. So they got daddy into the family automobile one evening and motored him over to Mrs. Smith's to a meeting of a literary circle. Upon being introduced to the hostess she exclaimed, "Oh, Mr. O'Bri'n, I am so delighted to meet you; I have heard so much about you. I understand you are a very well read man."

"You do, do you?" said OBrien. "Yes—Mr. O'Bri'n, have you read Spencer's 'Synthetic Philosophy'?" "I have not," said O'Brien. "But you have read 'The Four Horsemen of the Apocalypse'?" "I have not." "Surely you have read 'The Trail of the Lonesome Pine.'" "I have not." "Well, Mr. O'Bri'n, will you tell me, please, what have you read?" "Sure, I have red hair on me chist." (Laughter.)

Now I am going to try to be a little more serious, although I feel so good over this affair that it is questionable whether I shall succeed or not.

Professor Keller has gone over the early history of the Steel Treating Research Society and the events which have led up to the amalgamation, and I shall not dwell much upon that point. What he says of the Research Society is essentially true of the growth and development of our society. The Good Book records that God, shortly after he made man decided that it was not good for him to live alone, so he plucked from Adam a rib and from it made Eve. It seems that God has exercised the same wisdom in the creating of the Steel Treating family, and now that these two societies are to be joined, united, it is my happy privilege to give away the blushing bride, the Eve, made from the first rib of the first steel treating society. And it is with a great deal of pride that I present this buxom young amazon, glowing with health and strength.

It is the usual custom in ceremonies of this nature for the bride to assume the name of the groom, but in this case they have, both societies, both parties to the contract, agreed to adopt a new name, or rather a combination of the old names, sort of splitting the difference as it were. You know the original Adam and Eve split the difference and raised Cain. They did it again when they got Abel. (Laughter.) But I trust that no cain will be raised because of this union. On the contrary I hope and predict that this union will result in everlasting harmony, and in success in all those things for which we are organized.

There is just one phrase in Professor Keller's report that I don't believe he really meant. He spoke of the two societies as opposing societies. I don't believe they were opposing. They were simply competing, and it is a good thing to have competition for a time, but that time is past, and it is now time to concentrate our effort and eliminate the duplication.

My report upon the development and growth of the American Steel Treaters' Society is going to be very brief, because I know that you all came here principally to get the real meat of this convention, the papers, the latest developments in the heat treatment processes. Since our last convention, which was also our first convention, the number of our chapters has increased from 9 to 20, or an increase of 122 per cent. Our membership, taken from the books of the National Office, of members in good standing, which, of course, does not include some of the later admissions into the various chapters, was, at last report, 1,700—a little more than that, or a growth of over 270 per cent in the past year.

The very kind words that Professor Keller, President of the Research Society, has said of me are equally true of him. Since our very first meeting we have been hand in hand in this effort to bring together the two societies in a manner which would result in their ultimate greatest strength, which would result in the greatest benefit to the greatest number of men who are interested in steel treating work, either directly or indirectly. At every turn he has shown a disposition to give and take, and a real cooperative spirit.

Professor White should have the credit for the inauguration of this

movement. He took the initiative and he has worked faithfully and very conscientiously and successfully in this work. Few of you know of the enormous amount of time that he has devoted to this work, and it is highly fitting that we should honor him with the highest office which we have to give for the great interest which he has taken, and the success which he has achieved.

Appreciation of the efforts and good work of our officers, committeemen and members was expressed in the last issue of the Journal, September, and I shall not go into all the details now. I presume you have read it, but I do say that I wish I might more clearly express my feelings toward the men who have contributed so much to the advancement of our society, and to the art of steel treating in general. Those feeble words don't half express it. Usually when I have taken the floor before the members of our society, it has been to draw a picture of the future or to set up a target to shoot at, but today that part of the program rightfully belongs to our Chairman, Colonel White, who undoubtedly will be elected our President for the coming year, and I dare say that he will set us a lively pace.

There is one thought that I would like to add to the words of appreciation of those who participated in the offices and hard work of our society which was not expressed in the Journal. I want to repeat a quotation which I first heard from our good friend and worker Bill Bidle, of Cleveland, namely, "He climbs highest who helps another up." The good work done by these committeemen and officers certainly entitles them to climb high, and they undoubtedly will—sooner or later the result of such work will be manifested.

In giving my benediction on this happy pair of steel treating societies I want to relate an old story. This story is so old that you older heads have forgotten it and the younger ones weren't old enough to hear it when it went out of circulation. It is an incident occurring in Chicago a great many years ago—27 years ago to be exact. At that time the city of Chicago didn't have the nice, clean intelligent city government that it now has. Bill Thompson was an unknown quantity. It was at the close of the World's Fair when a proposal was made to the city government and to the aldermen and at that time the aldermen of Chicago were principally saloonkeepers, and incidentally I might say most all saloonkeepers were sons of aldermen. This proposal came to the council that the city should buy the fleet of gondolas that had been plying the lagoons of the World's Fair grounds. A considerable discussion was had, and some dissention arose over the amount of money involved in the purchase of the outfit, when one of them, more thrifty than the others, arose and said, "Mr. Mayor and Gentlemen: What is the use of buying up a whole flock of gondolas? Why not buy just one pair of them and let Nature take its course?" We now have here two perfectly healthy steel treating societies and I say by all means let Nature take its course, and may the resultant family be numerous, strong and wide-spread. (Applause.)

CHAIRMAN: It is with great pleasure that at this time I will ask Mr. L. S. Carrick, Treasurer of the Steel Treating Research Society, to make a report of the financial condition of that society. (Applause.) Mr. Carrick presented his report.

CHAIRMAN: It is with great pleasure at this time that I will ask Mr. Boissoneau, Treasurer of the American Steel Treaters' Society, to make his annual Treasurer's Report.

Mr. Boissoneau presented his report.

CHAIRMAN WHITE: The next on our program, as you will note, is the report of the Amalgamation Committee. As Chairman of the Amalgamation Committee it is with great pleasure that I am able to submit to you the following report. I have the report in front of me. It is somewhat bulky, as you possibly noticed, because we have attempted to keep in this report all of the official communications which have gone forth with respect to the Amalgamation. I know that you are all waiting with interest the technical paper which is to come in just a few minutes, and therefore, with your sanction and with your approval I will not attempt to read this report in any except a very general way.

. . . . Mr. White reads a general report, after which he joins the hands of Professor Keller, President of the Steel Treaters' Research Society, and Mr. T. C. Barker, President of the American Steel Treaters' Society as a symbol of the completion of the Amalgamation of the two societies into the American Society for Steel Treating.

MR. CARRICK: I move you that the report of the Amalgamation Committee be accepted and placed on file and the Committee dissolved, with the thanks of our society for their efforts. (Motion carried unanimously.)

REPORT OF COMMITTEE OF TELLERS

Chairman of Committee

There were 764 votes cast as follows:

Lt. Col. A. E. White for President	757
Mr. T. E. Barker, Vice-President for 2 years	755
Mr. T. D. Lynch, Vice-President for 1 year	751
Mr. W. H. Eisenman, Secretary for 2 years	751
Mr. W. S. Bidle, Treasurer for 1 year	764
Mr. H. J. Stagg, Director for 2 years	760
Mr. E. J. Janitzky, Director for 2 years	751
Mr. W. C. Peterson, Director for 1 year	760

CHAIRMAN WHITE: This completes, gentlemen, except for such incidental matters as may from time to time come up, the formal business meeting of the society. It is with great pleasure, therefore, that we are able now to open the meeting with our technical papers, for which I know you are all waiting with so much interest.

PRESIDENT WHITE: Men, it is with a great deal of pleasure this evening that all of us can be here in this room and join in our Second Annual Banquet. We know of no more fitting place for our convention at this particular period in our history than Philadelphia. It goes without saying that this is known as the "City of Brotherly Love." We know that in the early days it was in this city that the beginnings of our great country started. It is true that our Continental Congress met in other places than Philedelphia preceding the Declaration of Independence, but at the same time that big move which made this nation and had its start began here, and in the same respect we feel that at this particular period in our history when we are joining here as amalgamated societies under the name of the American Society for Steel Treating, we feel that it is fitting that we be here at this time.

Before going further it has been suggested that we ask the National Officers to stand, one at a time, so that you may all see them, and know that they are human. The first person we will ask to stand will be our First Vice-President, Mr. T. E. Barker of Chicago; Mr. T. D. Lynch, our Second Vice-President from Pittsburgh; Mr. William H. Eisenman, our

National Secretary, a man without a home; Mr. William S. Bidle, our Treasurer from Cleveland; Mr. Howard J. Stagg, our Director from Syracuse; Mr. Emil J. Janitzky of Chicago; Mr. Walter C. Peterson of Detroit; Mr. Frank P. Fahy, who has been appointed Director after we received, with regret, the resignation from the Board of Directors of Mr. MacFarland—Mr. Fahy of New York.

All remain standing, amid applause from members.

I assure you, men, it is with great pleasure that I am able at this time to turn the meeting over to our worthy Toastmaster, Mr. Joseph A. Steinmetz, who is President of the Aero Club of Pennsylvania, past President of the Engineers' Club, and in addition member of several Technical and Engineering societies. Major Steinmetz' forebears came over with William Penn on the good ship Welcome, so that it seems fitting that he should speak for the Philadelphia groups in extending welcome to the Steel Treaters of America. (Applause.)

THANKS!

At a meeting of the Board of Directors of the Society resolutions of thanks and appreciation were adopted for all those whose efforts had so materially contributed to the success of the week. The Convention Committees follow:

Convention Committees

Program and Papers—Arthur W. F. Green, Chairman; Walter M. Mitchell, George Howarth, L. W. Fawcett.

Exhibition—H. H. Clark, Chairman; E. J. Janitzky, A. F. Braid, J. C. Clark, D. K. Bullens.

Entertainment—F. A. Hall, Chairman; J. J. Crowe, D. K. Bullens, A. J. Collins, G. F. Pressell.

Plant Visitation—W. M. Mitchell, Chairman; E. G. Hall, William Knowles.

Ladies Entertainment—Mrs. Denison K. Bullens, Chairman; Mrs. Guy Passmore Bible, Mrs. Arthur W. F. Green, Mrs. Frank A. Hall, Mrs. George Kellar, Mrs. E. H. Barker.

PRESIDENTIAL ADDRESS BEFORE THE AMERICAN SOCIETY FOR STEEL TREATING

Lt. Col. A. E. White

It is with sincere feeling that I thank all of the members of the American Society for Steel Treating for the honor and trust they have conferred on me in electing me President of this Society. The heat treatment of iron and steel is a subject in which I have always been interested and it will be a great privilege for me to serve the Society and each of the members as its President.

The formal announcement of the amalgamation of the American Steel Treaters' Society and the Steel Treating Research Society into the American Society for Steel Treating was made this morning. Time does not need to be taken to go into that matter further; but in passing it is with much pleasure that I can look back upon the splendid co-operation given by the members of the Amalgamation Committee and the officers and members in both societies so that the amalgamation might become effective.

It is not fitting that I survey the work of the two societies during the past year. This survey has been splendidly presented by the officers of the two societies, respectively, namely, Mr. T. E. Barker, as President of the American Steel Treaters' Society, Mr. A. F. Boissoneau, as Treasurer of the American Steel Treaters' Society; Mr. John F. Keller, as President of the Steel Treating Research Society, and Mr. L. S. Carrick, as Treasurer of the Steel Treating Research Society. The splendid work which has been done by each of these two societies has been well portrayed and I only hope and I know that in doing so I am expressing the thought of each national and local officer and each member in the society that the same excellent program and good work done by each society individually during the past year may be carried on and performed during the coming year by the amalgamated society.

Since I am unable to view the affairs of the society retrospectively I believe it fitting to present at this time some thoughts relative to the scope and purpose of the society. The one large outstanding field for the society is SERVICE. In fact if it is unable to render service to its members and to the profession for which it stands, it has absolutely no place. Yet looking carefully over the hopes and purposes of the society there is no question but that it is rendering service in the fullest possible measure.

It hopes to keep its members informed on the various changes and improvements which take place from time to time in heat treatment. It wishes to bring to their attention through the medium of its "Transactions" and through various local and national meetings those developments in heat treatment which occur and the multitudinous phases of the field which are continually cropping up and which, unless our attention is especially directed toward them, escape our attention until there arises a period when they can be of intimate service and value to us. It hopes that through the medium of local meetings and the live papers and discussions which take place there, as well as through the medium of the "Transactions," that interest will be developed among the members and among those who should be enrolled among the members so that they will be willing not only to receive but also to give of themselves and of their knowledge so that their fellows may benefit and profit. It well behooves each one of us at this time to analyze ourselves closely and ascertain

whether we are sponges or diamonds. If the one we absorb and are shapeless, if the other we give out and give back many fold of that which is entrusted to us. If each one of us will take it upon ourselves to attend the meetings for the purpose of not only receiving benefit but also for the purpose of discussing various phases of the work with which we are familiar we will be surprised with regard to the extent to which interest will be created in the meetings and the benefit which each one of us will receive.

In this connection the qualifications for the various grades of membership are of a type slightly different from those found in most societies. To be a member one does not have to reach a stage in his profession obtainable only after a long apprenticeship and other possible favorable conditions. To be a member one only has to be interested in the work for which the society stands, to be above the adolescent age and interested in the society matters. Such a description makes possible membership in the society from all classes; those who occupy the humbler positions in the heat treatment shop as well as those who have risen to fields of distinction in the profession. There is no question but what we can all learn from those who are under us as well as from those above us and many times we can learn more from those under us than from those over us. The happy mingling of apprenticeship and experience, of the practical and technical, of user and designer should be of great value and assistance in strengthening the society.

It is hoped that this society will be able to be of great service and value to the profession for which it stands. It should bring into close contact the steel maker and the steel treater. It should acquaint the one with the troubles of the other and it should teach each to realize that the one is helpless without the other.

Further service which this society should render is that of bringing about better contact with the superintendents and managers of those plants engaged in heat treatment and the men in the shops. Not so many years ago there was a time when heat treatment was the work of technically ignorant but skilled specialists. It was handed down from father to son and there were many myths connected with it which it was believed must be followed in order to produce satisfactory results. That day has gone by and now there has cropped out a feeling among certain people that all that is necessary for the heat treatment of steel is a fire, a quenching tank, and material with which to work. This state of mind is just as harmful to the profession as that just mentioned and where found immediate steps should be taken to eradicate it.

In this society I see great possibilities for aid to our national growth and prosperity. Sir William Beardmore, in his address in 1916 as President of the British Iron and Steel Institute, called attention to the great disparity between the labor of skilled mechanics in that hour of great need in Great Britain, and that of the women who were brought into the munitions factories to take the places of their fighting brothers, husbands, and fathers in Belgium and Flanders. The disparity is so startling that it cannot fail but make one think regarding it, for the women though untrained, unskilled, and physically weaker than the men more than doubled the production records of these so-called skilled mechanics. Without, however, considering or entering minutely into this matter, is it not possible that there is something wrong in our social organization? Is it not possible that we are in need of something now lacking? Is it

not possible that through the channels of a society such as ours enthusiasm and interest in our work can be developed to a point whereby we will all give of the best that is in us? The humblest in our heat treatment shops can sit side by side with the superintendents and managers of the plants in which the heat treatment is done. They can meet on a common plane, they can discuss while they are there problems in which they are both interested. The one has as much right for discussion as the other and there need be no fear of possible consequences, in an open minded, liberal, and fair discussion. In fact the manager and superintendent should be able to learn what they need and the heat treatment man should be able to get what he needs much easier as the result of the open discussion than would have been possible otherwise. Therefore, it is my personal feeling that this society will be a great leveller in the best sense of that word and in so doing benefit all classes.

What this society can do for its members is possibly no better illustrated than by the experience of one of them associated with the Chicago chapter. Not many months ago he was in the postal service in Chicago. The publication of the American Steel Treaters' Society came to his attention and because he had formerly been in heat treatment work he looked it over and he felt at once as though he should return to the fold from which he had fled. He talked the matter over with several members in the American Steel Treaters' Society. He found a position and is now one of the superintendents of one of the large plants in Chicago. His pay is much better than it was as a clerk in the postal service but more than the pay is the fact that he has at last found himself and is happy and contented in his work.

This society should also be of great value and service through the stimulation which it should give to research work. I realize that there is a feeling on the part of some people that research work is impracticable, valueless, and a waste of time as well as money, but if we would only be sensible and look back upon conditions we would realize that we would not have advanced very far as a people if it had not been for research.

The work of Kelvin and Joule in the fifties when they showed that compressed gas upon issuing from a nozzle would be lowered in temperature, was not indicative at the time of anything of material value and yet today appreciable quantities of our oxygen and nitrogen are obtained from liquid air secured through the employment of the principles ascertained by Kelvin and Joule.

There is, in these days, much talk about the welding of ship plates rather than their riveting and it is not at all improbable but what there will be one or more ships produced this year with all of the joints welded instead of riveted. Yet this operation would not have been possible without the basic research done by Kelvin and Joule, for welding, except that of electric welding, requires oxygen and the oxygen obtained is secured in general in a manner laid down by Kelvin and Joule.

But coming somewhat closer to our own field, Sir Robert Hadfield has observed that by the use of hot tops he has cut down the wastage in steel ingots in his plants from 6.2% to 1.4%. This general procedure, in passing, is being adopted by all of our alloy steel mills. Some of the plain carbon steel plants are also adopting this method although the question of ultimate cost is one which prevents its more extensive use.

Within the past few years we have all witnessed the tremendous developments in alloy steel. Through researches relating to the composition and heat treatment of steel we are producing armor plate today

one quarter of the weight of that produced twenty years ago with superior impact resistance. In the same way we are producing guns today which are capable of resisting a pressure five times greater than they could have resisted twenty years ago. Also the research work on silicon steels has shown it to be more permeable under low magnetic fields than low carbon steels. As a result, silicon steels, for the past nine years, have come into electrical equipment capable of generating something like fourteen million kilowatts with a resultant annual saving of at least ten million dollars.

In view of all the achievements coming from research work, only a few of which have been mentioned, is it not proper, therefore, that this society should back and support such work as fully and as sympathetically as possible? Are we meeting our full duty if we fail to do so?

It is not right nor fitting at this time to state what your officers and directors will do during the coming year. You can rest assured that each one will do his full bit to the very best of his ability in fulfillment of the honor and trust that you have placed in him by his election to office. Yet you must keep firmly in mind the fact that these officers are merely your servants and are in office merely to do your bidding.

It is hoped that everyone who is in the society will feel that this is his society and will do his best to keep its record clean and make it an effective and efficient servant for the mass of membership as a whole. In this particular connection it is hoped that the local chapters will do as much for themselves as possible. The national officers will stand ready to help the local officers in any way possible but they hope that each local section will handle its affairs in the way which will meet with particular success in the district in which the section is located. It is believed that by placing the responsibility of the local section on itself that each member in the section will take more seriously and more deeply his responsibility than he would were the national officers to attempt to direct the affairs of the sections. It is realized that there is often times strength gained from centralized control but this strength is usually developed at the expense of interest and the national officers above all are desirous that each local section maintain and sustain interest in the society.

It falls to the lot of the President to appoint the national committees. You can rest assured that these appointments will be made only after due reference to the directors and the local chapter heads. That it may be possible for the committees appointed to assemble with the least possible inconvenience and with the greatest possible efficiency there will be a tendency to keep the membership of any committee in reasonably adjacent territory.

Of course, the one great spokesman for the society is its "Transactions." Through it the various activities of the society will be made public and the character and nature of the articles contained in it will be more or less an index of the work performed and covered. I know that I am speaking for those in charge of the publication when I say that an attempt will be made to make it accurate, yet simple and filled with live and useful material in the field of heat treatment.

Again I thank you all for the honor you have personally bestowed upon me. There is no honor but what carries with it responsibility and I trust that you will all feel that I am your servant and that whatever I can do or the directors and national officers can do to be of service to you and through you to the national society, will be taken care of to the best of our ability.

PROGRAM FOR AMERICAN SOCIETY FOR STEEL TREATING WAS CARRIED OUT ABOUT AS FOLLOWS:

Tuesday, September 14th

OPENING SESSION, 10-12 A. M.

Chairman—COL. A. E. WHITE, Chairman Amalgamation Committee
Address of Welcome...HIS HONOR, MAYOR MOORE, of Philadelphia
Response .....COLONEL A. E. WHITE
Appointment of Tellers of Election
Report of the Steel Treating Research Society..PRES. JOHN F. KELLAR
Report of American Steel Treaters' Society.....PRES. T. E. BARKER
Report of Amalgamation Committee.....CHAIRMAN A. E. WHITE
Paper

Papers

H. P. MacDONALD, Vice-President, Sneed & Co., Jersey City, N. J.
"The Electrical Heat Treatment of Steel"
Illustrated by Moving Pictures

Presented by Title

T. F. BAILY, President, The Electric Furnace Company, Alliance, Ohio.
"Relative Economy of Electric, Oil, Gas and Coal-Fired Furnaces"
Report of Tellers

NOONDAY LUNCHEON

Chapter Delegates and National Officers had Luncheon and Business Meeting at Commercial Museum.

Tuesday Afternoon, September 14th, 2 to 4:30

Chairman, COL. A. E. WHITE

Papers

O. E. HARDER, Associate Professor of Metallography, University of Minnesota.
"Microconstituents in One Section of a Metcalf Test Bar"
Illustrated by Lantern Slides.

J. L. McCLOUD, Foreman, Ford Motor Co., Tractor Div., Dearborn, Mich.
"Time, Temperature and Heating Media Functions in Hardening Tractor Worms"
Illustrated by Lantern Slides.

T. D. LYNCH, Research Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
"A Process for the Manufacture of Helical Springs for Heavy Duty"

W. G. LOTTES, Steel Expert, International Harvester Co., Chicago, Ill.
"Various Quenching Mediums and Their Application"
Illustrated by Lantern Slides.

Presented by Title

R. B. KERR, Foreman, Heat Treating Department, John Deere Harvester Works, East Moline, Ill.
"Hardening Hammer Die Blocks"

HENRY H. WIEGAND, Vice-President, E. J. Codd Co., Baltimore, Md.
"Furnace Door Screens"

PETER CHAMBERS, Partner, Angelus Steel Treating Co., Redondo, Cal.
"Forging Temperatures"

ROBERT B. POTTINGER, Manager, R. B. Pottinger, Racine, Wis.
"Forging, Welding and Tempering of Light Steel"

J. D. ANDREWS, District Manager, Brown Instrument Co., New York City.
"Pyrometers and Their Application to Steel Treating"

Tuesday Evening, September 14th, 8 to 10

Chairman, J. J. CROWE Chairman, Philadelphia Chapter

Papers

IRA T. HOOK, General Motors Company, Detroit, Mich.
"Factors Limiting the Use of Materials"

F. V. LARKIN, Head of Department of Mechanical Engineering, Lehigh University, South Bethlehem, Pa.
"Lessons Learned in the Manufacture of Munitions and Ordnance that can be Applied to the Peace Time Pursuits of Industry"

GUY P. BIBLE, Salesman, Horace T. Potts & Co., Philadelphia, Pa.
"The Relation of the Steel Salesman to the Development of Heat Treatment of Steel"

V. E. HILLMAN, Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass.
"The Efficiency of Various Quenching Mediums and Their Application"
Illustrated by Lantern Slides

Presented by Title

M. L. HARTMAN, Director Research Laboratory, The Carborundum Co., Niagara Falls, N. Y.
"Carborundum Refractories in Heat Treating Furnaces"

E. F. DAVIS, Sales Manager, Celite Products Company, New York City.
"The Function of Insulation and Its Application to Heat Treating Furnaces"

CHARLES U. GEESEY, Chemist and Metallurgist, The Garford Motor Truck Company, Lima, Ohio.
"The Functions of a Chemist and Metallurgist in the Motor Truck Industry"

J. J. de BOVES, President, Apex Steel Corporation, New York City.
"Heat Treating the Order"

EARL W. PIERCE, Metallurgist, Maxwell Motor Co., Newcastle, Ind.
"The Role of the Metallurgical Laboratory in Relation to the Inspection Department"

Wednesday Morning, September 15th, 10 to 12

Chairman, FRANK FAHY Ex-Chairman of the New York Chapter

CHARLES MORRIS JOHNSON, Director of Research Department, Crucible Steel Company of America, Pittsburgh, Pa.
"Properties and Microstructure of Heat Treated Non-Magnetic, Flame, Acids and Rust Resisting Steel"
Illustrated by Lantern Slides

W. H. MARBLE, Manager, American Stainless Steel Co., Pittsburgh, Pa.
"Stainless Steel, Its Treatment, Properties and Applications"

J. D. CUTTER, Metallurgist, Climax Molybdenum Co., New York City.
"A Suggested Method for Determining the Comparative Efficiency of Certain Combinations of Alloys in Steel"
Illustrated by Lantern Slides

Presented by Title

MARSHALL MEDWEDEFF, Metallurgical Engineer, Samson Tractor Co., Janesville, Wis.
"The Role of the Metallurgical Laboratory in Relation to Inspection"

H. C. LOUDENBECK, Engineer of Materials, Union Switch & Signal Co., Swissvale, Pa.
"Heat Treatment of Steel, Necessary Precautions to Obtain Uniformity"

W. R. WARD, Mechanical and Electrical Engineer, Lyells, Va.
"A Practical Aid to the Treatment of Steel"

NOONDAY LUNCHEON

The Chapter Delegates and National Officers had Luncheon and Business Meeting at the Commercial Museum.

Wednesday Afternoon, September 15th, 2 to 4:30

Chairman, FRANK FAHY

Papers

E. F. COLLINS, Consulting Engineer, Industrial Heating Devices, General Electric Company, Schenectady, N. Y.
"Relative Thermal Economy of Electric and Fuel Fired Furnaces"
Illustrated by Lantern Slides

W. A. EHLERS, Industrial Engineer, American Gas Association, New York City.
"Fuels and Their Application to Metal Treating"

GEORGE H. TROUT, The Smith Gas Engineering Co., Dayton, Ohio.
"Producer Gas for Heat Treating"
Illustrated by Lantern Slides

W. H. LYMAN, General Superintendent, Warner Gear Co., Muncie, Ind., and SETH A. MOULTON, Industrial Furnace Corporation, Boston, Mass.
"Relative Economy of Oil, Gas, Coal and Electric Heated Furnaces"
Illustrated by Lantern Slides

Presented by Title

H. G. HALL, Sales Manager, The Bristol Company, Chicago, Ill.
"The Essentials of Modern Pyrometry"

CARL CHRISTIAN JENSEN, Draftsman, Mahr Manufacturing Company, Minneapolis, Minn.
"The Current in the Thermo-Couple"

Wednesday Evening, September 15th

Chairman, J. FLETCHER HARPER Chairman, Milwaukee Chapter

Papers

T. Y. OLSEN, Tinius Olsen Testing Machine Company, Philadelphia, Pa.
"Most Recent Developments in Testing Machines and Equipment for Metallurgical Use"
Illustrated by Lantern Slides

E. P. STENGER and B. H. STENGER, Metallurgical Engineers, Thompson & Black, Detroit, Mich.
"The Effect of Heat Treatment on the Fatigue Strength of Steel"
Illustrated by Lantern Slides

ERIC E. BILGART, President, Pyromagnetic Instrument Co., Chicago, Ill.
"The Advantages of Magnetic Forces in Heat Treating"

Presented by Title

JAMES B. MOREY, Foreman of Annealing in Wire Mill, Atlas Crucible Steel Company, Dunkirk, N. Y.
"The Efficiency of Various Quenching Mediums, with their Practice and Applications"

ARTHUR N. ARMITAGE, Mesta Machine Company, Pittsburgh, Pa.
"The Pyrometer from the Standpoint of the User"

Thursday Morning, September 16th, 10 to 12
Exhibition Open from 9 to 5 P. M.

NEW YORK DAY

Chairman, WALTER GRAHAM Chairman, New York Chapter

Papers

G. R. BROPHY and Miss S. B. LEITER, Metallurgists, General Electric Co.,

Research Laboratories, Shenectady, N. Y.
"The True Action of Cyanide in Case Hardening Steel"
Illustrated by Lantern Slides

T. G. SELLECK, Alfred O. Blaich Company, Chicago, Ill.
"Case Hardening"
Illustrated by Lantern Slides

G. S. McFARLAND, Metallurgist, Jeffrey Manufacturing Co., Columbus, Ohio.
"A Research in Case Carbonizing"
Illustrated by Lantern Slides

R. L. GILMAN, Experimental Heat Treater, Standard Steel and Bearing Co., New Haven, Conn.
"Carburizing, Hardening and Tempering High Carbon Alloy Steels in One Hundred and Thirty Minutes"

Presented by Title

C. A. HAUX, Foreman, Avery Company, Peoria, Ill.
"Carburizing Temperatures Best Suitable for Steels of Various Carbon Contents"

FRANK J. McINTYRE, In Charge of Pyrometers, Hayes Wheel Company, Jackson, Mich.
"Practical Facts on Pyrometry"

A. BENSEL, First Vice-President, Driver-Harris Co., Harrison, N. J.
"High Temperature Resisting Alloys for Carbonizing"

WILLIAM G. CONNER
"The Carbonizing of Cast Steel Parts, Gears, Clutches, Etc."

Thursday Afternoon, September 16th, 2 to 4:30

Chairman, WALTER GRAHAM Chairman, New York Chapter

Papers

H. J. FRENCH, Bureau of Standards, Washington, D. C.
Moving Pictures of the Department of Metallurgy of the Bureau of Standards

J. L. THORNE, Metallurgist, U. S. High Speed Steel and Tool Corp., New York.
"Heat Treatment of High Speed Steel"

A. H. D'ARCAMBAL, Chief Metallurgist, Pratt & Whitney Co., Hartford, Conn.
"The Hardening of High Speed Steel"
Illustrated by Lantern Slides

Presented by Title

A. F. MacFARLAND, Metallurgical Engineer, Vanadium Alloys Steel Co., Latrobe, Pa.
"High Speed Steel and Some of Its Problems"

HENRY TRAPHAGEN, Metallurgist, Fast Feed Drill and Tool Corp., Toledo, Ohio.
"The Selection of High Speed Steel for Tools"

GEORGE PORTEOUS, Supervisor of Forge and Heat Treatment, Minnesota Steel Company, Duluth, Minn.
"High Carbon Open Hearth Steel Versus Crucible Tool Steel in the Manufacture of Miscellaneous Tools"

CHARLES N. RING, Chief Chemist, Ohio Steel Foundry Co., Springfield, Ohio.
"The Annealing and Heat Treatment of Miscellaneous Steel Castings"

HENRY E. HEMSTREET, General Foreman, Spring Department, Sheldon Axle and Spring Company, Wilkes-Barre, Pa.
"Heat Treatment of Truck Axles"

Friday, September 17th
Exhibition Open 9 A. M. to 5 P. M.
PLANT VISITATION

The following plants were open for visitors on Friday morning, from 9 to 12 o'clock:

Leeds & Northrop Co., 4901 Stenton Avenue—Pyrometers, Electric Furnaces, Electric Measuring Instruments, etc.

Edward G. Budd Manufacturing Company, 25th Street and Hunting Park Avenue—Automobile Bodies, Steel Stampings, etc.

Hess-Bright Manufacturing Company, Front Street and Erie Avenue—Annular Ball Bearings. S. K. F. Metallurgical and Research Laboratory.

AFTERNOON

The following plants were visited on Friday afternoon:

League Island Navy Yard, Hog Island, Midvale Steel and Ordnance Company.

LADIES' PROGRAM

The headquarters for the ladies was on the first floor of the Bellevue-Stratford Hotel, Rooms 108 and 109. A Secretary was at headquarters all the time to give information and for registration purposes.

Mrs. Bullens and her committee had arranged a very attractive program and the 75 ladies in attendance were very happy they had come.

The events were as follows:

Tuesday, September 14th

11:00 A. M.—Philadelphia ladies received out-of-town guests at Headquarters, first floor of the Bellevue-Stratford Hotel.

12:00 M.—Luncheon, Roof Garden, Bellevue-Stratford Hotel.

2:30 P. M.—Sight-seeing auto tour of Philadelphia, stops being made at Independence Hall to see the Liberty Bell, Declaration Chamber, etc., and also at the United States Mint. Points of interest include Historical, Business and Residential sections, including portion of Fairmount Park.

8:00 P. M.—Theatre party at Keith's.

Wednesday, September 15th

About 10:00 a. m. the ladies left on an all-day sight-seeing trip (auto) to Valley Forge, via Fairmount Park, Overbrook, Wynnewood, Bryn Mawr, etc. Ample time to enjoy historical Valley Forge.

At noon the ladies enjoyed the world-famous Pennsylvania Chicken and Waffle Dinner at Washington Inn, Valley Forge. Sight-seeing continued, returning about 4:00 p. m., arriving Philadelphia, 5:30 p. m.

Evening—Movie—Civilian Clothes.

Thursday, September 16th

Organ Recital at Wanamaker's Store at 11 o'clock and personally conducted tour of the store.

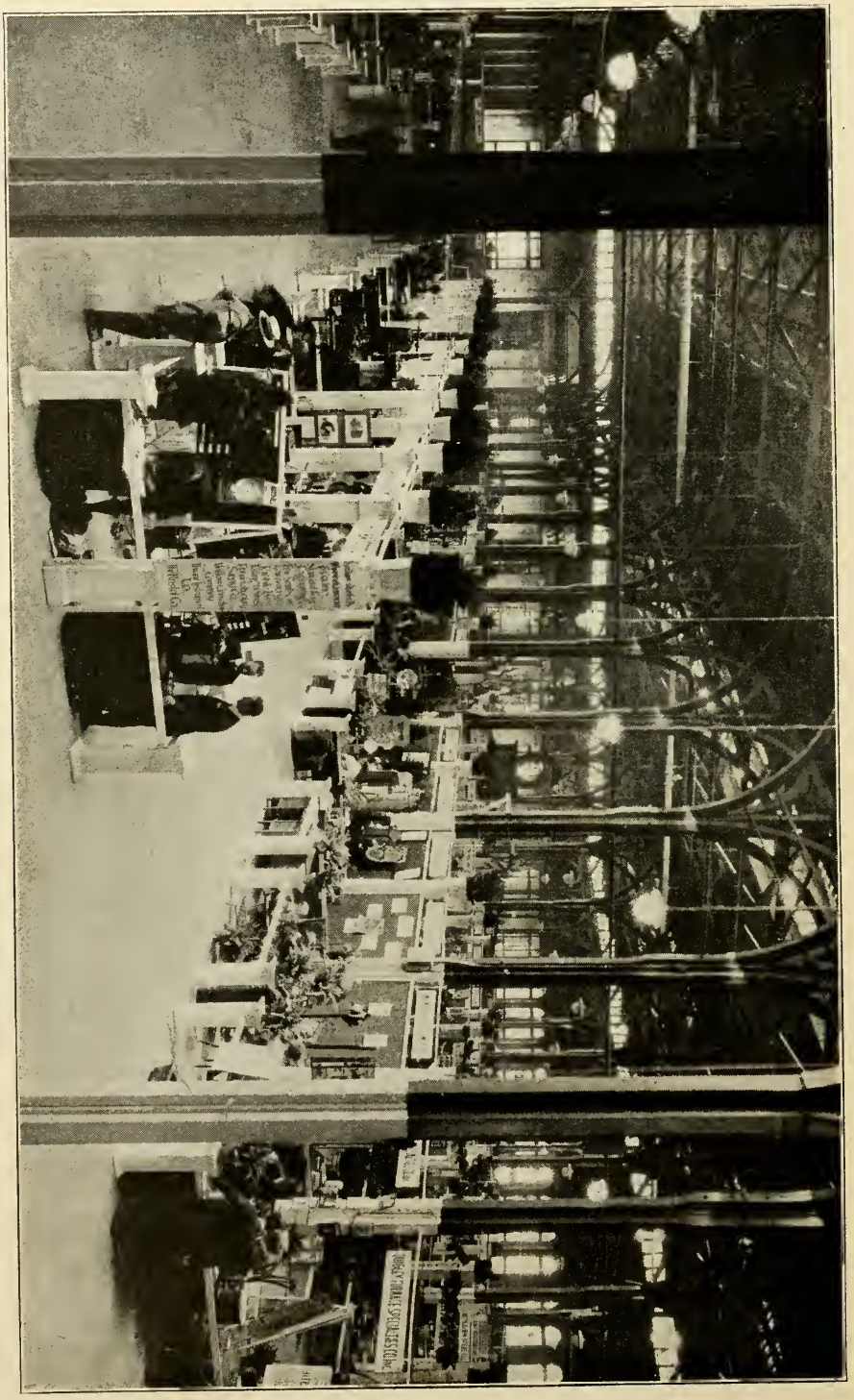
Visit the Curtis Publishing plant and trip to the Commercial Museum to inspect the exhibits.

Evening, 6.30 o'clock—Shore Dinner at Boothby's. 8:45 o'clock, Ladies joined men in time for speeches and entertainment at the Annual Banquet of the Society, Grand Ball Room, Bellevue-Stratford Hotel.

Friday, September 17th

Personally conducted trip to the Navy Yard and visit on various destroyers, battleships and submarines and several ex-German U-boats.

Evening, 8:00 o'clock—The Philadelphia Chapter entertained with an informal reception and dance in the Clover Room of the Bellevue-Stratford Hotel.



A view of one of the ten sections of the Wonderful Philadelphia Exhibition

LIST OF EXHIBITORS AT CONVENTION

Advance Furnace & Engineering Co., Springfield, Mass. Booths Nos. 134-135.

Ajax Electrothermic Corp., Trenton, N. J. Booth No. 301.

Alan Wood Iron & Steel Co., Philadelphia, Pa. Booths Nos. 251-252.

American Gas Association, New York. Booth No. 145.

American Gas Furnace Co., New York. Booths Nos. 131-132

American Metallurgical Corporation, Philadelphia, Pa. Booth No. 75.

Armstrong Cork & Insulation Co., Pittsburgh, Pa. Booths Nos. 194-195.

Atlas Crucible Steel Co., Dunkirk, N. Y. Booths Nos. 9-10.

Bausch & Lomb Optical Co., Rochester, N. Y. Booths Nos. 139-140.

Bell & Gossett Co., Chicago, Ill. Booth No. 205.

Bennett Co., W. R., Elmwood, Conn. Booth No. 137.

Bethlehem Steel Co., Bethlehem, Pa. Booths Nos. 61-62-235-236.

Blaich & Co., Alfred O., Chicago, Ill. Booths Nos. 63-233.

Bristol Co., Waterbury, Conn. Booth No. 175.

Brown, Clair H., Detroit, Mich. Booth No. 144.

Brown Instrument Co., Philadelphia, Pa. Booths Nos. 245-246.

Buda Co., Chicago, Ill. Booth No. 8.

Bureau of Standards, Washington, D. C. Booths Nos. 190-191.

Carborundum Co., Niagara Falls, N. Y. Booth No. 296.

Case Hardening Service Co., Cleveland, Ohio. Booth No. 204.

Celite Products Co., New York City. Booth No. 104.

Chemical & Metallurgical Engineering Co., New York City. Booth No. 226.

Chicago Chapter, A. S. S. T. Booth No. 1.

Chicago Flexible Shaft Co., Chicago, Ill. Booth No. 295.

Codd Co., E. J., Baltimore, Md. Booth No. 299-B.

Crucible Steel Co. of America, Philadelphia, Pa. Booth Nos. 273-276-277-280.

Dearborn Chemical Co., Chicago, Ill. Booth Nos. 87-200.

Disston & Sons, Henry, Inc., Philadelphia, Pa. Booth Nos. 89-198.

Driver-Harris Co., Harrison, N. J. Booth No. 133.

Electric Furnace Construction Co., Philadelphia, Pa. Booth No. 258.

Engelhard, Charles. New York, N. Y. Booth No. 297.

Fast Feed Drill & Tool Corp., New York. Booth No. 14.
Federal Tool & Alloy Steel Corp., New York. Booth Nos. 227-230.
Ferguson Furnace Co., Toledo, Ohio. Booth No. 228.
Ford Chain & Block Co., Philadelphia, Pa. Booth No. 80.
Frasse Steel Corp., Booth Nos. 117-118.

General Electric Co., Schenectady, N. Y. Booth Nos. 3-4.
Griscom-Russell Co., New York. Booth No. 244.

Hagan Co., George J., Pittsburgh, Pa. Booth Nos. 173-174.
Halcomb Steel Co., Syracuse, N. Y. Booths Nos. 188-189-192.
Haynes Stellite Co., New York City. Booth Nos. 170-167.
Heppenstall Forge & Knife Co., Pittsburgh, Pa. Booth No. 41.
Heinemann Electrical Co., Philadelphia, Pa. Booth No. 292.
Holz & Co., Inc., New York. Booth Nos. 248-249.
Hoover Steel Ball Co., Ann Arbor, Mich. Booth No. 15.
Hoffman Products Co., Harrisburg, Pa. Booth No. 11.
Hoskins Mfg. Co., Detroit, Mich. Booth Nos. 259-260.
Houghton & Co., E. F., Philadelphia, Pa. Booth Nos. 217-218.
Hungerford Brass & Copper Co., Philadelphia, Pa. Booth No. 256.

Improved Appliance Co., Booth No. 268.
Industrial Press, New York. Booth No. 150.
Ingersoll-Rand Co., Phillipsburg, N. J. Booth No. 149.
Iron Age Publishing Co., New York City. Booth Nos. 281-282.

Jones & Co., B. M., Inc., New York City. Booth No. 294.

Latrobe Electric Steel Co., Latrobe, Pa. Booth Nos. 275-278.
Leeds & Northrop Co., Philadelphia, Pa. Booth Nos. 68-214-215-216.
Leitz, E., Inc., New York. Booth No. 279.
Ludlum Steel Co., Watervliet, N. Y. Booth Nos. 185-186.

MacLeod Co., Cincinnati, Ohio. Booth No. 48.
Mahr Manufacturing Co., Minneapolis, Minn. Booth No. 222.
Mesta Machine Co., Pittsburgh, Pa. Booth Nos. 34-271.
Maxon Furnace & Engineering, Muncie, Ind. Booth No. 301.
Metal & Thermit Corp., New York, N. Y. Booth Nos. 242-243.

Midvale Steel & Ordnance Co., Cambria Steel Co., Philadelphia, Pa. Booth Nos. 77-78.

Milburn Co., Alexander, Baltimore, Md. Booth No. 81.

Modern Equipment Co., Taunton, Mass. Booth Nos. 49-50-51-52. Temperature control.

Montgomery Chemical Co., Detroit. Booth No. 203.

National Iron & Steel Publishing Co., Pittsburgh, Pa. Booth No. 247.

Oakley Chemical Co., New York City. Booth No. 241.

Obermayer Co., S., Pittsburgh, Pa. Booth No. 123.

Onondaga Steel Co., Inc., Syracuse, N. Y. Booth No. 206.

Paxson, J. W., & Co., Philadelphia, Pa. Booth No. 224.

Penn Seaboard Steel Co., Philadelphia, Pa. Booth Nos. 237-240.

Penton Publishing Co., Cleveland, Ohio. Booths Nos. 5-6.

Philadelphia Chapter, A. S. S. T. Booth No. 2.

Philadelphia Electric Co., Philadelphia, Pa. Booth No. 203.

Pittsburgh Inst. & Mach. Co., Pittsburgh, Pa. Booth No. 143.

Potts & Co., Horace T., Philadelphia, Pa. Booth No. 193.

Pyro Magnetic Instrument Co., P. O. Box 723, Chicago, Ill. Booth No. 287.

Quigley Furnace Specialties Co., New York. Booth Nos. 207-208-209-210.

Railway Mechanical Engineer, Woolworth Bldg., New York. Booth Nos. 211-212-213.

Riehle Bros. Testing Machine Co., Philadelphia, Pa. Booth Nos. 95-180-179.

Rockwell Co., W. S., New York City. Booth No. 88 and 197.

Rodman Chemical Co., Verona, Pa. Booth Nos. 283-284.

Roessler & Hasslacher Chemical Co., New York. Booth No. 187.

Rohde Laboratory Supply Co., New York City. Booth No. 178.

Scientific Materials Co., Pittsburgh, Pa. Booth Nos. 220-221.

Selas Co., New York City. Booth No. 291.

Shimer & Son, Porter W., Easton, Pa. Booth No. 146.

Simonds Steel Mills, Lockport, N. Y. Booth No. 196.

S. K. F. Industries, Philadelphia, Pa. Booth No. 42.

Smith Gas Engineering Co., Dayton, Ohio. Booth No. 96.

Spencer Turbine Co., Hartford Conn. Booth No. 285.

Spring Perch Co., Box A, Stratford, Conn. Booth No. 257.

Standard Fuel Engineering Co., Detroit, Mich. Booth Nos. 181-182.

Steel City-Testing Laboratory, Pittsburgh, Pa. Booth No. 250.

Steel Treating Equipment Co., Detroit, Mich. Booth No. 289.

Steuben Truck Co., Cincinnati, Ohio. Booth No. 257.

Strong, Carlisle & Hammond Co., Cleveland, Ohio. Booths Nos. 299A-300.

Supplee-Biddle Hardware Co., Philadelphia, Pa. Booth No. 138.

Surface Combustion Co., New York City. Booth No. 136.

Swind Machinery Co., Philadelphia, Pa. Booth Nos. 35 and 272.

Tate Jones & Co., Inc., Pittsburgh, Pa. Booth No. 130.

Taylor Co., N. & G., Philadelphia, Pa. Booth Nos. 22-23.

Thomas Co., Arthur H., Philadelphia, Pa. Booth Nos. 141-142.

Thwing Instrument Co., Philadelphia, Pa. Booth No. 176.

Tinius Olsen Testing Machine Co., Philadelphia, Pa. Booth Nos. 64-231-234.

U. S. High Speed Steel & Tool Corp., New York City. Booth Nos. 73-74.

Vanadium Alloys Steel Co., Latrobe, Pa. Booth No. 201.

Van Nostrand Co., D., New York. Booth No. 71.

Ward's Sons Co., Edgar T., Philadelphia, Pa. Booth No. 219.

Wayne Oil Tank & Pump Co., Fort Wayne, Ind. Booth No. 298.

Wheelock Lovejoy & Co., Inc., Cambridge, Mass. Booth Nos. 183-184.

Widney Test Laboratories, Chicago, Ill. Booth No. 69.

William Ganschow Co., Chicago, Ill. Booth No. 102.

Wilson-Maeulen Co., New York City. Booth Nos. 76-79.

Yarnell-Waring Co., Philadelphia, Pa. Booth No. 37.

EXPRESSIONS

It is always interesting to know how the exhibitors feel towards an exposition after it is over. We should remember they are all keen, wide awake business men who have authorized an advertising expenditure and in many cases have spent thousands of dollars to make a display. If you will read the following you will acquire an inkling into the brain activity of big business. Other opinions will be published later:

Mr. W. G. Barstow, of the Mahr Mfg. Company:

It pleases us to state that the results obtained from the exhibit of the Mahr Mfg. Company's equipment at the Philadelphia Convention, eclipses those obtained at the 1919 show at Chicago, which was, at that time, probably the most successful exhibit we have ever put on.

Mr. Earl Converse, of the Dearborn Chemical Company:

It is a great advancement over the Convention in Chicago, and I believe we have received more real benefit and good, coming in contact with more people really interested in our line, than we have in many previous Conventions which we have attended in 35 years, which goes to show that this industry is of such vital importance in bringing together the control departments of steel manufacturers with their managers and owners.

Mr. W. F. Scully, Advance Furnace & Engineering Company:

From the viewpoint of our Company, the exhibition has been an entire success. We obtained an order for the new type of moving floor furnace which we exhibited, and have prospects for at least 25 more. Also obtained several propositions for complete oil and gas furnace systems for our standard furnaces. We are all very glad we exhibited.

Mr. G. L. Reichhelm, American Gas Furnace Company stated:

I think that the officers should be congratulated on the wonderful success of the Convention. We never exhibited at a show where the inquiries came from such an intelligent class of men seeking our products. The benefits which we have received far outweigh the comparatively slight expense of the show.

We have sold a number of furnaces and would have sold a great many more if we had been prepared to make deliveries.

Mr. J. B. Shelby, Driver Harris Company:

The Driver Harris Company desire to express their appreciation to the officers of the Convention for their co-operation in arranging this particularly beneficial exhibit. We feel particularly gratified at the class of exhibitors who have inquired at our booths regarding our various products.

We look forward to a continuance of these Conventions, and are arranging to be suitably represented again next year.

It seems an excellent opportunity for reaching the class of people and the particular individuals whom we wish to interest in Cast Nichrome and its heat resisting qualities.

Mr. Myall, Supplee Biddle Company:

Speaking for the Supplee Biddle Company of Philadelphia, we can say without hesitation, that we have had a highly successful week. Our booth has been well patronized, and we have lined up important pros-

pects for a considerable volume of business. Be assured that we will be one of your exhibitors at your next Convention.

Mr. A. R. Beves, Surface Combustion Company, states:

I feel that the Exhibition was highly successful. Many very interesting inquiries, those from old customers and from interested parties have been received, and also orders have been secured direct through our exhibit at this Convention. I feel we will be very greatly interested in having an exhibit at the Convention next year.

Mr. E. E. Bilgart, of the Pyromagnetic Instrument Company states that although it was their first exhibit, the benefits derived therefrom were very much beyond expectations. We feel that it affords both those interested in the art of heat treating as a commercial item, and those interested from a business standpoint, an opportunity of discussion as to the adaptability of methods, materials and inventions. It brings the salesmen in contact with the very men he wants to meet. This exhibit has given us an opportunity of making new acquaintances. We have received orders for over 11 Pyromagnetic Indicators, and have prospects for a great many more orders.

Mr. F. A. Calhoun, Eastern Representative, Standard Fuel Engineering Company:

It is the opinion of the writer and his associate, Mr. Baad, that the Exhibition and Convention of the American Society for Steel Treating has been very successful in helping us meet new customers and receiving many inquiries. All of the people who have visited us, came to the Convention with one purpose in mind and that was to look into the matter of a purchase of heat treating equipment.

Mr. Trout, Smith Gas Engineering Company:

I wish to congratulate the officers of the Society in having had such a turnout of high quality men at the Convention, rather than a large body who were merely curiosity seekers. Ninety per cent of the people who called at our booth, were people who talked intelligently and were highly interested.

Mr. W. G. Sours, of the Riehle Brothers Testing Machine Company:

We feel that the show from a standpoint of our line of testing machines has been very successful to us. We have had many visitors examine our working demonstrations, and they have shown an intelligence on the proposition which speaks well for the class of people in attendance. In addition to that, we have received many prospects for future business, and we are sure that these will materialize.

Mr. Durgin, of the Modern Equipment Company:

I was very much pleased with the class of people who have examined our exhibition, due to the fact that the sightseers were absent. We have secured a large number of excellent prospects and feel sure that we will be able to close many of them.

Mr. W. C. Tyler, of the Wm. Ganschow Company:

The Exhibition from the standpoint of inquiries and prospects of

future orders, has been more successful than we anticipated. I feel sure that these will materialize into business that will more than pay for the expense of two booths instead of the one that we had.

Mr. Gossett, of the Bell-Gossett Company:

The Exhibition has been more than gratifying. Many orders have been received, and the prospects are very excellent.

Mr. C. C. McDermott, of the Brown Instrument Company, states:

The inquiries and sales we have received and made at the Convention have been far greater than we expected. The attendance has seemed to be of the buying variety, and not many curiosity seekers. Not only good volume in attendance but good quality.

Mr. H. H. Harris, Quigley Furnace Specialties Company, states:

We have exhibited at over 50 Conventions, and we do not know of any Convention with the possible exception of the Foundrymen's Convention, where we have derived more benefit. The majority of the visitors at our booths were executives and officers of their companies, and we had very few idlers or people who could not be considered as prospects.

We had over 2,000 visitors and handed out more than 400 samples of Q-Alloys, each of which we received a signed receipt for. In all we consider our time and money well spent, and firmly believe that the American Society for Steel Treating has made further progress in two years than any other similar organization. We give our heartiest support to the Society and its every enterprise.

Mr. Wooler, Philadelphia, representative of Strong, Carlisle & Hammond Company, stated:

I was highly gratified by the excellency of those in attendance, inasmuch as they were men who had been sent by the Purchasing Departments to investigate the furnaces and to make reports. There is no doubt that it is the most reasonable method possible to secure get in contact with the users.

Mr. Lazear, of the Chicago Flexible Shaft Company:

My opinion of the show is that the crowds that came in were actually interested. The man that came to the show, came because he was interested in heat treating. We had comparatively few curiosity seekers. We have secured a large number of good prospects. It is my opinion that the show is worth ten times what the expense cost us.

Mr. Wiegand, of E. J. Codd Company:

I think that the show has been a great success. We have reached the very people we want to meet, and no curiosity seekers. We have received a great deal of interest in the Chain Furnace Doors and have a large list of prospects.

Mr. K. P. Himley, Selas Company:

I am very glad we exhibited at this Convention, as we were able to see the very men that we were anxious to meet, such as the Metallurgists and Managers of the plants. We have secured a large list of prospects, which will no doubt result in good business.

Mr. H. Goldsen, Wilson-Maeulen Company:

I think the Exhibition was a show that only those who were actually interested in their line of business came to see. They came to see how to better their product. We have made more actual orders for Pyrometers and Rockwell Hardness Machines than we ever dreamed of getting.

Mr. F. G. Davis, Atlas Crucible Steel Company:

The Convention at Philadelphia was undoubtedly a wonderful success. We are highly pleased with the results of our exhibit, and are confident that there will be a very material increase in our business in the very near future as a direct result of this Convention. We have met the very men we have wanted to meet.

Mr. R. E. Talley, George J. Hagan Company:

We had Presidents of big concerns come in and sit in our booth for over an hour, who were interested in our furnaces. The people who attended the Convention were interested and not curiosity seekers or souvenir hunters. We secured many good prospects, 80 per cent of which are good and will develop into future business.

Mr. Ray, Heppenstall Forge & Knife Company:

We feel well paid for the labor and expense that we have gone to, to install a booth at the Convention, and it is my personal opinion that at the next Convention we should be represented in a more thorough manner than this year.

There were no souvenir hunters, but every one who stopped at our booth, were either customers or prospective customers, and were interested in die blocks and the heat treatment of same.

THE FUNCTION OF INSULATION AND ITS APPLICATION TO HEAT TREATING FURNACES

E. F. Davis*

A paper read before American Society for Steel Treating Convention, Sept., 1920

The urgent needs of the government for various furnaces, during the World's War which has been brought to a successful end, resulted in many types of furnaces being hurriedly designed and placed in operation. Quantity rather than quality predominated in the minds of furnace designers. But the scarcity and steadily rising cost of fuel of all kinds, the increased operating costs, and keen competition during the past few years has stimulated interest on the part of manufacturers to increase the efficiency of all manufacturing operations and the industrial world's attention has been drawn to many losses in heat treating which heretofore were neglected. Prominent among these is the loss of heat through furnace walls.

Every manufacturing concern is carefully searching and investigating every process and method that would tend to be an economical solution to his fuel problem.

During the past few years the manufacturers have had to meet a constant increase of cost for fuel and also great difficulty in some cases to get it at any price, therefore, if the manufacturer is able to increase the efficiency of his furnaces by the better utilization of his fuel he will then be able to keep his fuel cost per unit of output nearly constant.

Many old theories in furnace design have been forced to give way to more modern practice of producing a specified product and the manufacturer has learned that indifferent heating with any old kind of a furnace would not give a product that would meet modern heat treating specifications.

The most important progress has been made in furnace design, insulation, durability, economical applications of heat, furnace control and ease of operation.

Burners have been designed providing a definite known mixture of fuel and air which has done away with the evils and the loss due to improper combustion. The control of products of combustion by means of flues and dampers properly located, have added greatly towards uniformity of heat. This has in many cases replaced the old methods of allowing the flame to come directly in contact with the steel causing heavy oxidation and uneven heating.

For many years it has been a well recognized fact that heat, and hence fuel were being lost through the furnace walls, but until recently it was not known how much this loss amounted to in dollars and cents; nor was it known that the larger part of this loss could be eliminated by the use of an efficient and durable insulating material.

The first and most important step for the conservation of fuel is to insulate the space being heated.

Inasmuch as the heat loss of any heat treating furnace is a function of the size of the exposed surface and hence of the size of the heated space, it follows that the appliance should be well adapted to the work to be done as to its size.

Intimate knowledge of materials suitable for construction of heating devices is important so that in all cases the material most suited for

*Sales Engineer Celite Products Co.

the purpose is selected and the amount of heat absorbing material is limited to that required for strength and durability.

If an oven is constructed with little or no insulation, the heat loss through its walls is great and the expense of the fuel is considerably larger. If this same oven is insulated the heat loss is materially decreased.

It can be mathematically proven that the maximum economy obtained when the cost of the heat loss for a given period of time is equal to the fixed charges of the additional expenditure for heat insulation for the same period of time. For given conditions of price of fuel and heat insulating materials, the working temperature and the load factor of the oven, the amount of heat insulation required for maximum economy can therefore be readily determined.

It often happens that a furnace is built of twice the capacity of its predecessor and upon completion of same it is discovered that the larger furnace has more uniform temperature throughout and also requires considerably less than twice the amount of fuel to keep it running.

The reason for same being not owing to the heavier construction but also that the holding capacity of a furnace increases approximately as the cube of the linear dimensions, while the radiating surface increases as its square, so that loss from radiation is less than twice the primary amount from the furnace of double capacity.

From this it will readily be seen that not only will furnace efficiency vary between the different types but also between the same type according to their size, design and the process carried on within them.

If the refractory material used possesses a fusion point or softening range higher than the maximum temperature to which they are exposed, (which is always the case in heat treating furnaces) it would be most

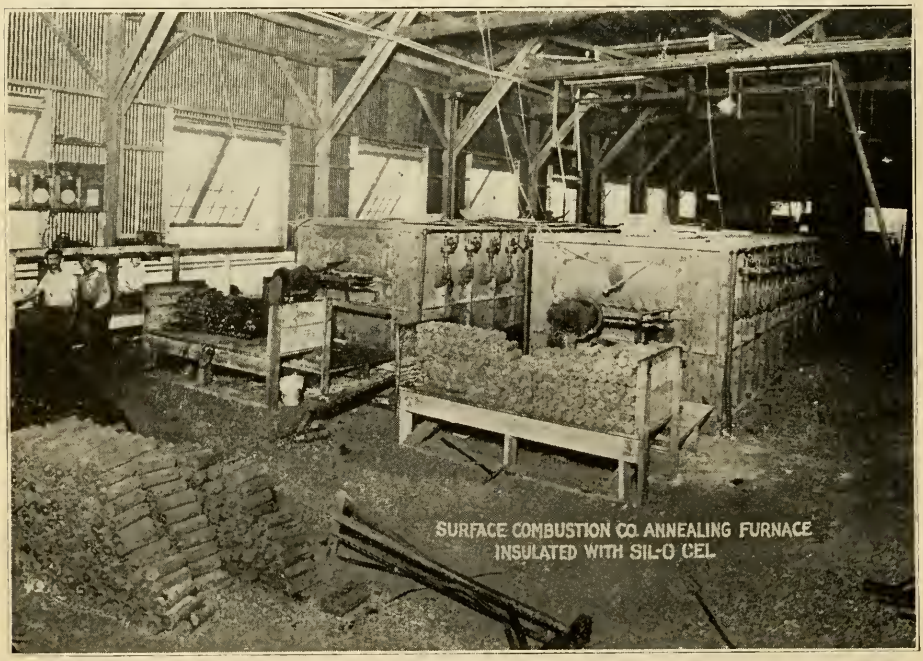


Figure 1

desirable that they should be backed up with materials which are non-conductors of heat, for radiating losses would then be at a minimum.

It is readily seen that quicker heats can be made where the temperature is uniform. The temperature being equal throughout the furnace, the rate of heat absorption is alike throughout the charge.

A large amount of rejected work that is charged to bad steel or the heat treating department can often be traced to poor heating in the forging process. If the metal is not heated uniformly throughout the mass it cannot flow evenly under the flows of the hammer or between the dies of the press, consequently the grain is not closed in a uniform manner. If the furnace temperature is easily controlled, disastrous over heating of the charge is minimized.

A definite amount of heat is required for raising the temperature of

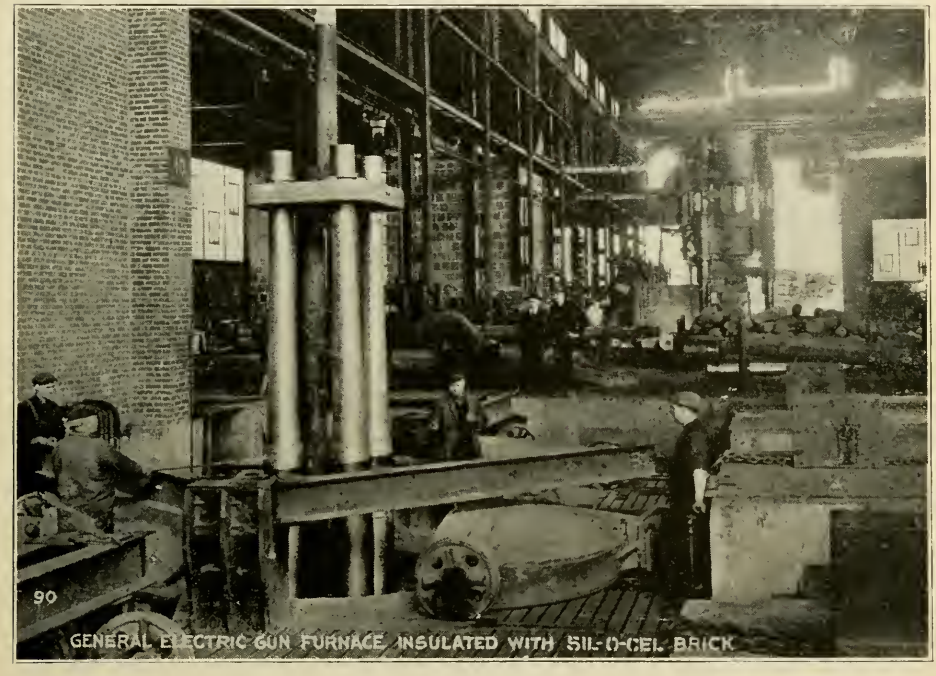


Figure 2

the work through a given range, irrespective of the length of time consumed in heating. However, with a given amount of material being heated through a definite range and consuming a definite amount of fuel, if the heating is accomplished in one half the time double the amount of fuel will be required.

The total weight of the work heated, multiplied by the degrees rise in temperature multiplied by the specific heat of the metal gives the amount of fuel required in B. T. U. The specific heat of iron which is the heat in B. T. U. required to raise 1 lb. 1° F. is 0.125.

Efficiency

The efficiency of a heat treating furnace is expressed by the ratio of heat supplied to heat usefully applied in the furnace.

$$\frac{\text{Heat usefully applied}}{\text{Heat supplied}} = \text{efficiency of furnace}$$

The heat usefully applied is governed by four requirements.

1. Heat necessary to raise the temperature of the charge to the point at which the desired reaction takes place.
2. Heat to balance reaction if reaction is endothermic.
3. Loss from stack through the producers of combustion according to the fuel in use.
4. Loss through the wall through conduction which is dissipated by radiation and conduction varying according to the construction.

Heat Conservation

Many combustion furnaces in use today suffer from overventilation as the result of improperly proportioned flues or vents. In such cases the draft is so excessive that the hot gases of combustion are carried through the furnace at a speed so great that no opportunity is allowed for them to give up much of their available heat, which is thus carried away with the flue gases and lost to useful work.

When the proper precautions are not taken much heat is lost by conduction through, and radiation and convection from, the furnace walls to the room. When it is desired to concentrate all of the possible heat upon the work in the furnace and an appreciable amount of this heat is lost in this manner, low efficiency is the result.

The flow of heat through bodies by conduction may be either a help or a hindrance, according to the use to which we put the material. In some cases it is desired to conduct heat as quickly as possible; in others it is desired to lessen or prevent the conduction of heat as much as possible. Copper tubing is introduced into a water heater so that heat energy may be conducted through the walls of the tube to the water within as quickly as possible.

We cover the outside boilers with lagging in order to keep heat from being conducted away. Here we want a poor conductor of heat and we say we have used an "insulator."

There is perhaps no field in which neglect of simple economies is more prevalent than in the field of heat insulation, and the manufacturer and superintendent of the heat treating departments should give the insulation of their heat treating equipment careful consideration in the building or selecting of their furnaces for future work.

Each new application presents a new engineering problem and requires investigation of present equipment. When these are determined the accurate data available on the most advisable fuel will allow a thorough comparison to be made on a commercial basis which represents the factor of interest to manufacturers. These investigations will also determine whether the application of the fuel will be a success from an operative view. It isn't very comforting to know that you have an apparatus capable of operating well and find after it is installed that it is not applicable to your requirements or represents no saving.

While the success of any installation demands a well designed apparatus, the important factor in the consideration of such an installation is whether the installation is really warranted, and if so, the proper application of the fuel to its most economical use.

Heat Transmission

In connection with a discussion of insulation, brief mention of heat

transmission is of interest, furnishing as it does, the fundamental considerations that govern insulating work.

Heat is a form of energy consisting of molecular vibration of a periodic character, subject to the general laws of wave motion. It can be reflected, refracted and dispersed by creating the proper condition within the walls. In other words, we can increase or decrease the rate of heat flow within certain limits, by altering the design and the materials of construction of the walls.

Heat is transferred from one place to another by three different methods—conduction, radiation, and convection.

Conduction is the action taking place in which heat energy is passed from a particle at a higher temperature to one at a lower temperature by virtue of their contact. While this method of heat transfer applies to the three states of matter—solid, liquid and gaseous—it is of magnitude only in solids.

By radiation heat is transferred from one body to another without any material agency by wave motion, this applies only to the gaseous state of matter.

Convection is the process of heat transfer in which some portion of the body whose temperature is raised moved to another place where the temperature is lower, tending to raise the temperature of the medium. This method of transfer is limited, therefore, to liquids and gases.

Taking a simple example of the application of these methods, as, for instance, a furnace wall, the heat is transmitted from the combustion chamber by radiation direct from the burning fuel to the inner surface of the firebrick walls, and by convection currents resulting from the moving gaseous product of combustion. Following the heat passes through the walls, and, ultimately is lost by radiation from the outer surface enhanced by convection caused by air movement outside of the wall.

Conduction is responsible for the greatest portion of the heat transmitted, through the furnace walls. The rate of this conductivity through the wall depends upon the ability of the materials used in construction to resist the movements of the heat waves. This immediately applies to our consideration of the matter of wall insulation, for without proper insulation the heat losses assume a surprising total in the aggregate—an amount of actual fuel loss that often is not appreciated.

Rate of Heat Flow

The amount of heat conducted through a unit area from one part of the body to another is proportional to the thermal conductivity of the body through which the heat passes and inversely proportional to the distance between the two parts of the body. In other words, the conduction of heat through a solid body from one place to another is a direct function of the conductivity of the body and the difference in temperature of the two planes, and an indirect function of their distances apart. This is identical with Ohm's law for transfer of electrical energy.

The heat transferred from one body to another by radiation is proportional to the difference of the fourth powers of the absolute temperatures of the two bodies. While this is strictly true only of the ideal "black-bodies" the variation is so small that, for all practical purposes, this relation holds good in ordinary procedure.

Requirements of Insulators

The requirements of the insulating backing for the more refractory

lining is rather severe. An ideal material should have the value, and be sufficiently refractory so that no fusing or excessive shrinkage would take place in that portion which is in direct contact with the highly heated refractory wall. It should not be decomposed or be changed greatly in volume at the temperature, and it should, furthermore, be of light weight, unaffected by moisture, of convenient form, readily applied by unskilled labor and low in cost. It should be of such composition as not to react upon or attack either the refractory material or the metal shell of the container, even in the presence of moisture; i. e., it should contain no free acid radicals, and should not be broken or caused to settle by vibration or heat. It should not have high expansion, and it should be sufficiently elastic to take up strains between the lining and the shell produced by temperature changes.

While this is a rather formidable array of requirements, there are products upon the market which fulfill practically all of them.

Selection of Insulation

In any high temperature apparatus, if the heat can be prevented from being dissipated from the outside of the furnace, the temperature of the furnace is made more uniform in the zone of reaction, and consequently the capacity is manifestly increased without additional fuel consumption. Furthermore, overheating at the source of heat in the effort to bring as much of the furnace as possible into the zone of reaction, is materially reduced by preventing loss through the furnace walls. This has the ultimate effect of lowering the temperature at the source of heat, greatly increasing the life of the refractories and the capacity of the furnace.

In general the question of insulation does not concern itself so much with the saving in fuel, though this is also an important item, as with the general effect produced by confining the heat generated to points of maximum effectiveness. The higher the cost of fuel the more necessary it is to look closely to preventable losses to obtain an economically operated furnace.

By the use of an insulating material such as Sil-O-Cel, heat treating besides assuring a degree of quality that cannot be otherwise attained owing to the even temperature maintained throughout the furnace is really more economical than the methods generally used. The fuel economy is greater, the operation is more convenient through absence of temperature fluctuations, and the speed of heating is considerably increased.

This follows because heat is definitely applied to all sides of the charge at once so that very little soaking is required beyond the time necessary to bring the charge up to the required temperature. In furnaces which have no insulation and where the heat is not evenly applied, a long soaking period is required to assure a fair measure of uniformity, by heat travel through the material itself to the colder portions of the heating chamber owing to the heat being lost through radiation.

In general, in high temperature furnace construction, there are two separate and distinct factors which must be considered in securing an effective wall.

The first of these is to provide a material having the ability to resist the action of high temperatures, sufficient mechanical strength, and possibly the property of resisting corrosive slags, gases, etc., without spalling or being eroded.

The second is to prevent the excessive loss of heat due to conduction from the interior of the furnace to the outside where it is lost. Rarely is a good refractory material a good insulator; usually it is necessary to back up the refractory lining with some material having a much lower heat-conducting capacity.

The requirements of the insulating backing for the more refractory lining are rather severe. An ideal material would have the following properties: It should have an extremely high insulating value and be sufficiently refractory so that no fusing or excessive shrinkage would take place in that portion which is in direct contact with the highly heated refractory wall.

It should not be decomposed and it should furthermore be of light weight, uneffected by moisture, of convenient form, readily applied by unskilled labor, and low in cost. It should be of such composition as not to react upon or attack either the refractory material or the metal shell of the container even in the presence of moisture. It should contain no free acid radicals, and should not be broken or caused to settle by vibration or heat. It should not have high expansion, and it should be sufficiently elastic to take up strains between the lining and the shell, produced by temperature changes.

Practical Consideration of Heat Transfer

In the practical consideration of heat transfer in our furnaces, conduction may be neglected in its relation to combustion since any conducting medium must receive its heat initially either by convection or radiation. Heating by convection will be done most easily and efficiently by raising some radiating medium to the greatest possible temperature.

This is the method in use in the usual form of furnace. The heat of convection of the products of combustion comes in contact with the furnace walls which rise in temperature and radiate their heat to the work. In the case of convection heating all the fuel should be burned and no free oxygen should be present in the flue gases, since to get the hottest products of combustion there must be complete combustion and a minimum weight of flue products.

To raise the radiant elements to the maximum temperature there must again be the condition of complete combustion of the fuel together with minimum flue products. There is another item to be considered in the case of radiant heat. The hotter the radiant element, the more rapidly can heat be transferred to a given object. For instance, a radiating element which is at 2,500 deg. Fahr. will transmit nearly twice as much heat per sq. ft. of its area in unit time as when it is at 2,000 deg. Fahr. Hence it becomes necessary to maintain the heating element at a maximum temperature during the absorption of heat from the element, and that can only be done by supplying a maximum amount of fuel to that element.

We can now summarize by saying that the best results in any heating operation will be obtained when the fuel is completely burned and the flue gas contains no free oxygen or carbon monoxide. It is also seen that when heating is to be done by radiation it is desirable to have a radiant element that can be controlled in temperature and varied nearly up to the theoretical flame temperature.

Given a furnace in which a maximum of radiant heat is produced and a minimum of excess air, it is clear that this furnace must be highly efficient.

By the use of an efficient insulating material the operating flame temperature will be brought near to the theoretical flame temperature and hence the amount of radiant energy materially increased.

Furnace Walls

In the design and construction of heat treating furnaces the conductivity of fire clay is of extreme importance. In oven furnaces where a large volume of heat is required, particular attention must be paid to the conductivity of the firebrick employed, so that the thickness of the wall may be determined to give the most economical working.

In the case of small furnaces which are used only during the day, and require to be heated up to a working temperature each morning, the time required for this preliminary heating up will to a great extent depend upon the thickness and conductivity of the wall. In such cases the quantity of brickwork should be a minimum; 2½″ brick backed up by 2½″ of a good insulating material such as Sil-O-Cel.

For large heat treating furnaces which are working continuously the thickness of the wall should not be less than 13½″; a 9″ course of firebrick backed by a 4½″ of Sil-O-Cel Insulating Brick.

In general, in high temperature wall construction, there are two separate and distinct factors which must be considered to produce an effective wall.

The first of these is to provide a material having the ability to resist the action of high temperatures, sufficient mechanical strength and, possibly, the property of resisting corrosive slags, gases, etc., without spalling or being eroded.

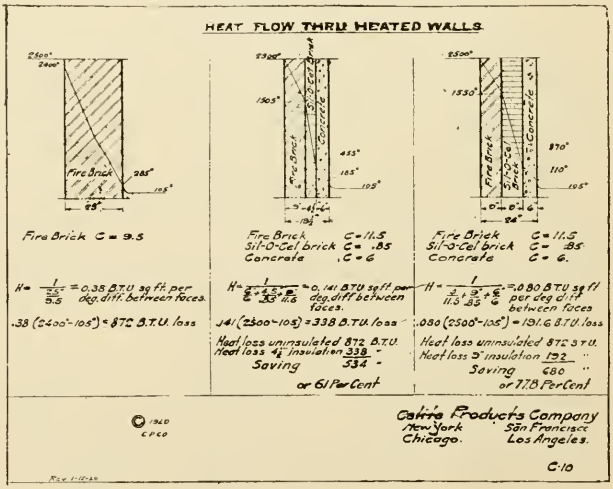


Figure 3

The second is to prevent the excessive loss of heat due to conduction from the interior of the wall to the outside where it is lost by radiation or conduction.

It is rare that a good refractory material is an insulator; usually it is necessary to augment or back up the refractory with some material having a much lower heat conducting capacity.

The three most important points in considering wall construction are:

1. A wall of sufficient thickness to withstand the strain.
2. A sufficient thickness to prevent excessive heat loss.
3. A wall sufficiently thin to conform to combustion chamber design.

Walls vary greatly in practice depending upon how much consideration has been given each of these points, in a thin wall the concentra-

tion of heat in a deep chamber is avoided but excessive wall radiation results. On the other hand in excessively thick walls the loss is reduced but higher cost and repair charges are entailed.

Proper Heating Furnace Insulation

That the firebrick lining of a furnace supplies sufficient insulation against heat losses is the common impression among furnace users, and but little attention is paid to the fact that the vicinity of a bank of furnaces is almost unbearable to one unused to the work on account of the excessive heat coming from the furnace.

The usual type of furnace usually consists of a firebrick lining and an outer casing of cast iron or sheet steel. In order to properly determine the amount of heat loss from the exposed plate it is necessary to know the temperature of the outer surface and the rate at which heat leaves the surface. Pyrometers may be used to determine the temperature of the furnace and the other data may be derived as usual. From a curve given by Charles R. Darling in "Engineering," London, the following approximate figures may be taken:

Temperature of Surface, deg. F.	B. T. U. escaping per sq. ft.
100	60
200	320
300	700
400	1240
500	1900
600	2680

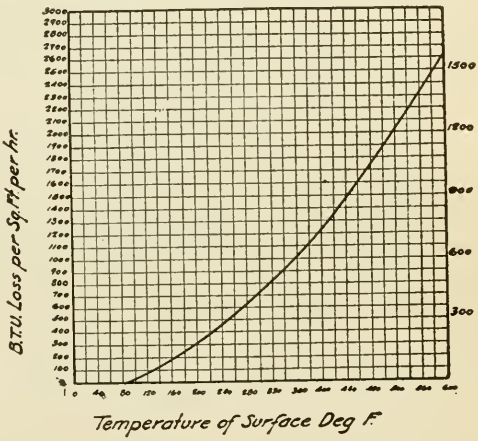


Figure 4

One reheating furnace for steel possessing an exposed surface of 430 sq. ft. (330 sq. ft. in the sides and 100 sq. ft. on the top) was observed for a week at normal working and readings of surface and internal temperatures were taken at stated intervals:

Location	Degrees F.
Interior	1450 to 1600
Exterior Plates average	300
Exterior Firebrick	390

The plate readings were taken from the sides, while the firebrick was used for a top and unprotected. Assuming the loss of heat from the firebrick to be at the same rate as from iron the total heat loss was $330 \times 700 + 100 \times 1100 = 341{,}000$ B. T. U.

Experiments with an electrically heated furnace on which readings were first taken with it unlagged, and then with lagging in place, showed the amount of saving which may be anticipated in such an insulation:

B. T. U. Escaping From Furnace Per Hour

Internal tem. deg. F.	Without lagging	With lagging
400	450	150
800	1150	450
1200	2150	950
1600	3350	1650
1800	....	2050

The saving effected was more than 50 per cent over the entire range observed, greatly exceeding in value the cost of the additional insulation material and providing an additional reduction in maintenance cost.

Since the loss of heat through radiation is a function of the skin temperature, we can readily estimate from this the heat loss in B. T. U. Darling has given the heat loss from a heated metal wall for various temperatures, as shown graphically in Figure 1.

If closer figures for heat loss are desired, or temperature gradients throughout the various components the following formula is very useful:

$$H = \frac{1}{\dfrac{1}{K} \times \dfrac{d \times d_1 \times 1}{c \times c_1 \times K}} \times (t_2 - t_3)$$

Where

H—heat loss in B. T. U. per sq. ft. per hour.

t_2—temperature of the furnace gases.

t_3—room temperature.

K—a factor for heat emission.

d and d_1—thickness of furnace wall.

c and c_1—coefficients of conductivity of the various wall components, at the temperatures operated.

Conversely, to obtain the temperature drop or gradient, the reciprocal value is used for each material and divided into the heat loss in B. T. U. per hour. Temp. drop — $\dfrac{H}{\dfrac{K}{1}}$ between the inside gas temperature.

Temp. drop — $\dfrac{H}{\dfrac{c}{d}}$ for each component of the wall.

This gives the loss from a vertical wall. It has been found by actual experiment that the heat loss from a horizontal surface is approximately 22% greater than from a vertical surface.

Editor's Note: To be concluded in the November issue of the Transactions.

THE APPLICATION OF PYROMETERS TO THE HEAT TREATMENT OF STEEL

A. M. Redding*

Read before Buffalo Chapter

It is the purpose of this paper to take up the various types of pyrometer equipment, mentioning the advantages and the particular applications of the equipments; to discuss the considerations entering into the selection of pyrometer equipment for some of the usual heat treatments, and to describe a few typical first class installations. The phrase "type of equipment" as used here does not refer to the various manufacturers of pyrometers, but rather to the function of the equipment, i. e., indicating, recording, controlling, etc. The discussion will be limited to pyrometers of the thermocouple class wherein the measurement is made with either a galvanometer or a potentiometer.

The simplest type of pyrometer installation is the indicating system. It is the cheapest equipment, and likewise it gives the least information. The operator obtains only intermittent readings of the temperature, and it is not likely that he can keep in mind what has gone before, especially when he is concerned with several temperatures. He knows only the present temperature of each couple, which is only a part of the story.

The next step in the development of pyrometer equipment is to add to the indicating system a recorder. The indicator now is for the convenience of the furnace operator and is used by him when the reading it gives is a sufficient guide. For further information, or when concerned with rates or time intervals, he refers to the recorder. The record gives a check on the furnace operator's work and affords a ready reference in connection with subsequent physical tests of the product, or if the heat treatment proves to have been faulty.

The progression next leads to the central station system, that is, the recording and signalling system. The first central stations were manually operated, but soon the development of the instruments permitted the automatic central station.

If there is such a thing as an ideal pyrometer equipment, it is the automatic central station. The furnace operators are guided by signals given them by means of colored signal lamps and deviation meters mounted at the furnaces. The lamps and deviation meters are operated automatically by recording instruments in the control room, at the same time records are being made showing how closely the furnace operators follow the signals. The instruments being grouped together in the control room are in a safe place and can receive the best of care as one man only has charge of them.

If a furnace temperature varies outside the prescribed limits, the operator's attention is attracted by the flash of a signal lamp as soon as this change starts to take place. After his attention is gained he is guided further by the indications of the deviation meter which show him how many degrees the temperature is off and how fast and in what direction it is changing. This does away with the dangers that are present when a fireman reads several temperatures in succession from an indicator and, trying to remember them, goes to the various furnaces to make the adjustments. The chances are that he will forget or confuse the temperatures, and then rely on his eye to make the adjustment. With the signal lamps

*Leeds & Northrup Co.

and deflector the fireman has a continuous indication at each furnace. This indication is not merely in the form of a temperature reading in degrees, but really says to him "you are high 30°" or "you are 40° low" or "your temperature is O. K." The effect of this is the same as if the foreman stood with him all day telling him what the temperature was and the direction and amount of adjustment to make. The result is that the temperature is held just about as close to the desired value as is humanly possible. And this feat can be accomplished with a poorer class of labor. It does not take long to make an inexperienced man understand that the red light is showing him his furnace is too hot and the blue light, too cold, and that the pointer in the deviation meter is to be kept on zero.

These conditions just described are obtained by virtue of the instruments alone. They are due to the perfected design and the enlarged capabilities of the modern pyrometer. The central station idea itself also has its important advantages. Briefly the central station simplifies and renders more efficient the supervision and operation of the heat treatment. It is done in this way. The work is scheduled thru the various departments of the plant. The foreman of the heat treatment knows beforehand when certain work is coming to his department. He knows what that work is. He knows from his previous records exactly what treatment that work is to receive. From his own schedule he knows which furnaces will be free at that time to give the treatment; suppose there are four such furnaces, two of which will have just finished a treatment at 1500° F. and two at 1425° F. Suppose the new work in question is to be treated at 1500°. The foreman therefore schedules that work to go to the two furnaces which will be just finishing up at 1500° and the complete information in regard to this is noted, preferably on a chart in the central station. When this new work is delivered to the heat treatment department it is brought in and laid in front of the two furnaces which are to do the job as shown by the charter schedule. When a furnace is free it is charged with a lot of the new work. The furnace is already up to temperature or nearer to it than any of the others so that no needless time nor fuel is spent in bringing it up, as usually happens when the furnaces are selected at random. When the charge is ready to come out, this fact is signalled to the fireman. The responsibility for applying the correct temperature for the correct length of time has not been given to the fireman except insofar as he has had to follow the signal lamps, and this is watched by the foreman or assistant foreman on the floor. The operator in the central station is really the active brain of the heat treatment. He keeps the schedule revised and up-to-date. He knows what charge is in each furnace, when it went in, the treatment it is receiving, and when it shall come out. It is of course necessary that this operator be capable of carrying this responsibility and fulfilling these duties, and then only ordinary ability is required of the men at the furnaces.

To sum up, for the central station, the foreman has absolute and complete control of the entire situation. He knows from a glance at his schedule what is in each furnace, the treatment being given and the present stage of the treatment. New work coming in is scheduled so as to get efficiency in time and fuel. The furnaces are being controlled as closely as if the foreman were standing behind each man continually, and directing him.

The last type of equipment to be considered is the complete automatic control system. This is not yet in common use as it is a recent

development and in fact for some furnaces it is still impractical. The majority of present installations of automatic temperature control equipments are on electric furnaces or ovens. This is because of the simplicity and ease with which the heat supply can be controlled in electric furnaces. This is usually accomplished by means of automatic switches or rheostats and it is a very simple matter to control these from a potentiometer recorder. With other types of furnaces the application of automatic control is being held up by the difficulty of providing a mechanism which can be operated by the recorder, and which in turn will properly control the supply of heat to the furnace. Nevertheless some of these installations have been made and are giving satisfaction depending upon the efficiency and proper operation of the valve adjusting mechanism. In one plant in particular, two circular continuous electric furnaces and two circular continuous oil fired furnaces are used for hardening and annealing automobile spring leaves. Automatic control was installed on the electric furnaces and gave very satisfactory results. The management then wished to install automatic control on the oil furnaces to obtain the same benefits. Accordingly one of the men designed and built a small motor operated mechanism to regulate an oil burner, the motor being controlled by a potentiometer recorder. This apparatus was installed on one burner of a four burner furnace, and, after a little experimenting to determine the proper setting of the other three valves, it was found that by leaving the three burners permanently set and controlling the fourth automatically, the furnace temperature was held within plus or minus 10° F.

When it comes to making the selection of pyrometer equipment for a particular installation, we are confronted with a problem which unfortunately in many cases is treated too lightly. We install pyrometers not to gratify any whim, not for decorative purposes, not just to spend money, but to enable us to improve operations and obtain results which otherwise are beyond reach. A pyrometer equipment usually means a fairly large first cost. This money is not being thrown away but is being invested to pay dividends. These dividends will not be as large as they might if the pyrometer equipment has not been selected as being best suited to that work. When making the selection the problem is not merely what make of instrument to secure, but also what will be the function of that equipment.

There must be taken into consideration such factors as the following: complete cycle of furnace treatment was not a success, as the heat had not penetrated to the center of the forging, although the work had been soaked for a time which previously had been considered to be sufficient. However, the inspectors would not pass the treatment. A test run was made with thermocouples imbedded at different depths in holes drilled in the forging. One couple was at the very center of the forging, another on the surface and others spaced in between. These couples as well as couples in the furnace gases were recorded on a multiple point recorder. The record showed that when holding their usual furnace temperature it required over twice the time they had been allowing for the center of the forging to come up to the temperature, and here the time may be measured in days rather than hours. Succeeding treatments utilizing the information thus gained were successful.

The indicating and recording equipment is probably the type which will best meet the needs in this kind of work. The use of the signal lamp system is prevented by the fact that the number of thermocouples used

in one furnace may be as great as twenty, and the cost of the signalling equipment would be prohibitive.

In the heat treatment of smaller work such as axles, springs, crank shafts, etc., the principles are very nearly the same as in the work just taken up, but all is on a smaller scale. For either the hardening or annealing of this kind of work the best system, if it can be used, is the signal lamp and deflector system, or in other words the automatic central station. The advantages of this type of instrument are obtained with an equipment for only one furnace as well as 50 furnaces. The advantages of the central station idea, i. e., the facilities for scheduling the work and securing increased efficiency in the operation of the whole department, are more apparent, the larger the installation.

Should it happen that one of these treatments is given in an electric furnace, there is an automatic equipment to control the treatment which gives very interesting results. The pyrometer is a one point two temperature controller connected to two thermocouples, both in the same furnace. One couple has its hot end in immediate contact with, or buried in, the work, and is called the contact couple. The other is located in the atmosphere of the furnace preferably near the heat source. The control discs on the potentiometer recorder are so set that as long as the contact couple is below a predetermined temperature the furnace couple tends to hold the furnace at a high temperature to force heat into the charge, but after the contact couple has reached the desired temperature, the controller automatically throws over and tends to hold the furnace couple at a lower temperature, which is usually set at a value just sufficient to supply the radiation losses, thus holding the charge constant.

One application of this was in gun treatment work, the contact couple was in immediate contact with the gun in a G. E. furnace and the furnace couple was located near the resistor winding. The controller was set to hold a comparatively high temperature, about 1800° F., and this temperature was maintained until the contact couple showed that the surface of the work had reached, say 1450° F., when the control shifted and the temperature of the furnace couple was gradually and automatically reduced to a temperature just above the finishing temperature of the work, and held until the work was thoroughly "soaked." When the control first throws over to the lower temperature, the interior of the charge will absorb heat from the surface sufficient to cause a rapid fall of the surface temperature below 1450° F., when the relays will operate in the reverse order and the original connections will be restored, which will again raise the temperature to 1450° F. and again throw over the control. This cycle of operations will continue until the interior has ceased to draw heat from the surface of the charge, or in other words until the charge is heated thru, and thereafter the control will remain thrown over to the low temperature setting which is only slightly above the finishing temperature, and just enough to supply the radiation losses of the furnace. Thus the charge is heated at the maximum rate without danger of being overheated.

The pyrometer equipment for carbonizing heats could also be of the automatic signalling or central station type. The indicator and multiple point recorder equipment would give good service but it is rather second choice. For carbonizing the temperature is held constant for a considerable time, and therein the automatic signalling excels. The temperature

that is to be kept constant, is the temperature of the work itself, within the box. This can be best accomplished by controlling the temperature of the gases in the furnace, for there is a lag between these two temperatures and if the gases are controlled within close limits the work will be between still closer limits. It is necessary to know the lag, or the relation between the gases and the work, particularly during the heating up stage so that the correct time will be allowed to get the desired depth of penetration in the work. This temperature relation can be found by experiment, by placing one or more bare couples in contact with the work and recording their temperatures with that of the gases.

Box or pot annealing affords a very interesting application of pyrometers. The requirements are somewhat similar to those in carbonizing work, in that the temperature with which the operator is concerned, the duration of which must be for sufficient time, is the temperature of the work within the box or pot; while the temperature most readily measured and the one which is directly controlled is that of the furnace gases. It is essential for a successful treatment that the temperature be held sufficiently long for the work to become uniform throughout its mass, while on the other hand, holding the temperature for more than this time is simply a waste of time and fuel.

Probably the most successful equipment for this work, of which the writer knows, consists of a two temperature recorder for each furnace. One of the temperatures recorded is that of the furnace gases; the other is the temperature inside the pot or box, if there is only one box per furnace, or inside the most representative box if there are several boxes in a furnace. Both temperatures are shown on the one record sheet. As the furnace is heating up the fireman holds the temperature of the gases sufficiently above the temperature of the work to secure a good rate of heating. As the finishing temperature of the work is approached, the gas temperature can be cut down until it is just enough above the work to supply radiation losses and hold the work steady. Even though the overshooting of the temperature on heating up would not spoil the treatment, still it is a waste of fuel, and so should be avoided. Having a record of the two temperatures, the fireman can observe both the "cause" and the "effect." He can anticipate by several minutes, changes in the rate of heating, or deviations from the steady temperature, and take action to successfully make or prevent these changes as the case may be.

Another equipment which has been applied successfully to this kind of work is the indicator and multiple point recorder equipment, reading the temperatures of the furnace gases only. However, in each case it has been necessary to make experimental runs with some thermocouples in actual contact with the work, to determine the relation between the work and the gas temperatures. This method does not give as close temperature control as the two temperature recorder method, but then it is claimed by some, and with reason, that a close control is not a requisite for success in this treatment. On the other hand a close control will surely not detract from the success of the treatment, and it will give a better fuel economy.

When we consider such work as the hardening of tools and dies, we are tackling a very large and difficult problem. Hardening is being done by a number of methods and with widely differing results. All types of pyrometer equipment are being used. Broadly speaking, it can be said that the signal lamp and deflector system should be given first choice

with the indicator and multiple point recorder next. There is a recent very interesting development in the field of hardening tools, dies, gears, etc., which should be taken up at least briefly because of its very marked advance in method and results. That is the Hump Method.

In this method the outward manifestation of the changes in internal structure which take place when steel is heated past the so-called critical or transformation point is employed to indicate when the work should be withdrawn from the furnace. A vertical electric furnace is used and its construction and operation are such that all parts of the charge are at a uniform temperature and heat up uniformly. It is found that the rate of temperature increase has a marked influence upon the properties exhibited by the steel after quenching. The rate of heating is easily controlled in an electric furnace. All parts of the charge pass through the critical point at the same time, and thus avoid stresses and distortions which would follow from unequal expansion or contraction if different parts of the work passed through the critical point at different times. The passage thru the critical point is indicated by a hump in the curve that is being drawn on the potentiometer recorder chart. Before quenching it is necessary to heat the work a certain distance above the critical point, this distance depending upon the mass and shape of the steel, the quenching medium employed, and the qualities desired. The exact further heating to be allowed after passing thru the critical point is learned by experience or trial, but once known, all uncertainty as to the result is practically eliminated, and results can be repeated. This method eliminates all errors due to non-uniform temperature in the furnace, failure of the work to reach the furnace temperature, and incorrect information regarding the location of the critical point. The Hump Treatment equipment itself also has these advantages: the work is protected against fresh supplies of oxygen, thus avoiding scaling or decarbonization; electric furnaces are long lived and have low upkeep charges; working conditions in the heat treating room are improved, due to lower temperatures and absence of smoke and noise of burners; the hardening and drawing furnaces are cleanly in operation and can be installed in comparatively small space in the machine shop; and others of lesser importance.

The general need for pyrometers in heat treatment is known to be present and, what is more important, that need is receiving wider recognition. This is to be expected for the advantages of the proper pyrometer equipment have been demonstrated over and over again. The recognition of the need for pyrometers was given a decided impetus by the war and the conditions under which we were working at that time. There was a demand for steel in all forms for ordnance and other purposes. In most cases the steel had to meet very strict and severe specifications because of the purpose to which it was to be put. And then it was found that these specifications could not be met, sometimes not at all, other times at least without any degree of certainty and regularity without the use of pyrometers.

And still it is very interesting to observe the widely differing views held by men who have to do with pyrometers, in regard to the importance of these instruments. Some of the hardeners and others of the old school will glance contemptuously in the general direction of the pyrometer, make a few terse remarks concerning pyrometers and the man who will use one, and go on with their work judging temperatures by their eye and using other approximate guides which their experience has taught

them. Another man claims enthusiastically that a pyrometer should be the steel treater's Bible, the information it gives accepted in blind faith. These are the extreme views, and yet there are times when each one is just about right. There are some jobs on which a pyrometer is of very little, if any, help. There are other cases where the pyrometer tells the complete story and enables a man to turn out better and more uniform work than he could possibly do alone. The proper view to adopt is one that is somewhere between these two. You surely must have faith and confidence in your pyrometers else they are of no value to you. This must not, however, be a blind faith; but must be a faith born of knowledge and understanding of the instruments and of the theories and principles underlying them; and a faith that is strengthened by careful supervision and checking of the equipment. Get to know your equipment and understand it. Get to know how much important information the equipment will give you, how much you may rely upon it and also know its limitations. Then use the equipment to the limit, get as much help from it as you can, but do not try to exceed that. Do not thoughtlessly expect your pyrometer equipment to do the impossible.

STEEL AND THE FORGE SHOP MAN

F. L. Moister*

"Mysterious Failures of Steel" were of common occurrence twenty years ago. The investigation of steel has advanced to such a stage that it is no longer classed with the "Mysteries." Its broader use, knowledge of how to impart the desired qualities by heat treatment, and the changes in structure which take place under varying conditions of work and temerature, were arrived at by comparison of findings and interchange of ideas and methods. It was by close study and careful examination in the shop and laboratory, that so much is known about this most complex of all metals.

The laboratory investigation is extremely important, but the commercial application of the findings of such investigations is generally in the hands of the Forge Shop Man who is supposed to follow instructions without question, but who seldom knows what he is aiming at or what he has accomplished. Hence the suggestion in the following that he be enlightened enough to perform his part intelligently and to know what properties his work is intended to impart to the steel.

Why is the heat treatment of steel generally described in such highly technical terms that the forge shop man, who performs the actual operations, has but a vague idea of the meaning? Does the metallurgist think it such an intricate problem, known only to the laboratory investigator, that the shop man cannot grasp it?

One argument has been advanced that if the shop man knows too much about the science, for it is a science, he will not follow instructions but work according to his own ideas. This is preposterous for should such condition arise it would be an easy matter to put your hand on a man scheduled for immediate discharge.

Another weak argument is, if the shop man be kept too well posted on the results of his work, there would be many embryo metallurgists in the shops, the profession soon become common and overcrowded.

The forge shop man need not know the exact chemical composition

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of the steel as this is within the province of the metallurgist, but he should know that the aim of heat treatment is to change the grain of the steel to such a degree of fineness and toughness as will insure the results being equal to requirements, that the composition is such that if he carries out the specified treatment the results must be within stated limits, that if the results are not what is desired it is evidence that he did not follow instructions in every particular.

The exact treatment should be determined before instructing the shop and not changed each time the tests show failure. This is very important, and gives the shop man confidence in the metallurgist, for confidence and perfect co-operation are absolutely essential to success.

It is not necessary to talk to the shop man about eutectics, micrograin, macrograin, ferrite, pearlite, sorbite, etc., etc., but use the word grain, with qualifying adjectives if advisable. Steel is of granular structure, coarse grain, that is a grain that is coarse to the eye means inferior physical qualities, while fine grain means superior qualities.

A carpenter knows how to work various woods to best advantage although no two are alike, but he can do nothing to change the physical characteristics of the wood.

A machinist is given a piece of steel and a dimensioned sketch or drawing to which it must be finished. He has no control over the quality of the metal. His work is mechanical, setting the piece on the machine, selecting the proper tool, controlling the cut and measuring accurately so that when the piece leaves his hands it will be of correct dimensions and finish. He sees the completed piece and knows if his work has been good or bad.

Steel is the most mobile and complex of all metals, capable of the greatest structural changes, yet the forge shop man remains in ignorance of its characteristics and has but a vague idea of what his work is doing to the structure of the metal. He is given a piece of steel about which he knows nothing to heat and forge into a definite shape, not appreciating that he is changing its structure as well as its shape or that a great deal depends on careful heating and skillful forging in order to produce a piece in which the grain is in the best possible condition to withstand the stresses put on it in service, or for subsequent heat treatment. His thought is to heat and forge it as quickly as possible with hammer work reduced to a minimum. To arrive at this, which to him is the very acme of achievement, the steel is heated too hot and forged too quickly to obtain the fine grain desired.

This condition exists in most forge shops and it should be corrected by a series of instructions with illustrations to the forge men so that they know what they are doing to the steel other than to bring it to the desired shape. The points on which he should be enlightened are:

1. The principle methods of making steel, Bessemer, Open Hearth, Crucible.

2. The effect of the common chemical components on the physical properties of the steel, carbon, sulphur, phosphorus, manganese and silicon.

3. Defects found in forging billets and blooms,—piping, sponginess, seams, splits and torn edges, how to detect them, what causes them, and their effect on the forgings.

4. The effect of heating and forging at various temperatures.

5. The effect on the grain of the steel of normal cooling and of

delayed cooling from last forging temperature. In many shops forgings are piled from the hammer and cooling delayed. This is very injurious, particularly in large forgings, and complicates subsequent heat treatment.

6. The refining effect on the grain of annealing. That delayed cooling is not annealing, but that heating after the forging is cooled, followed by normal cooling is annealing.

7. The effect of quenching at varying temperatures.

8. The softening and toughening effect of the draw.

9. What is meant by tensile or ultimate strength, elastic limit, per cent of elongation, per cent of reduction of area and what they indicate in the physical properties of the steel. Tensile test pieces should be pulled in the presence of the forge man.

This list might be extended indefinitely but many other points could be brought out without enlarging it so as to make the instructions comprehensive, practical and within the grasp of the forge shop man.

Any honest workman wants to turn out good work. Any good forge man wants to turn out good forgings. How much better it would be to enlighten him in the fundamentals of metallurgy so that he knows whether his work be for good steel or not. He knows many things about how to work steel into shape to best advantage which the metallurgist does not know. If his mechanical skill was supplemented by a knowledge of the structure of steel, he would turn out better work, the metallurgists' problem be simplified, and the ultimate result would be toward greater efficiency and better components in our structures.

PRODUCER GAS FOR HEAT TREATING

Geo. H. Trout*

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It is not difficult to recall the days when hand fired coal furnaces were used for all kinds of furnace work. The labor attached to doing work by this method was excessive and as wages were increased, fuel oil became a very convenient medium of obtaining heat. It is surprising, though, that more attention was not paid to the application and adaptability of fuel oil to furnace work. This was possibly due to the fact that fuel oil became very cheap and because of its high flame temperature, it was comparatively easy to obtain almost any desired temperature without much effort.

As fuel oil increased in price, some study was made of burners, but only recently has furnace design been given any consideration from the point of greater economy and adaptability to the work in question.

For low temperature work the general practice has been to utilize fuel oil by any one of the three following methods:

First: With an excess of oil with its attendant incomplete combustion and smoky furnace.

Second: With a heavy air excess, so that the flame temperature of the oil under complete combustion could be held down.

Third: In the Muffle furnace.

Each of these methods has been found to be inefficient.

Fuel oil is now not only high priced but the supply is inadequate, and the evidence clearly indicates that both these conditions probably will be permanent. That price is not the sole consideration in this day

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of striving for a better product, is evidenced by the fact that some concerns are now operating electric heat treating furnaces even at a greater cost in the endeavor to obtain better results.

Another fuel available for heat treating is producer gas.

There are two kinds of producer gas, "Hot" or "Raw" gas and cold, clean gas.

Producer gas from bituminous coal in its raw state carries large quantities of tar vapor and lamp black. When the gas is used hot, the greater part of the tar is not condensed, but remains in the gas. It is usual in this process to endeavor to keep the temperatures of the gas above the condensing point of the tar in transporting it from the producer to the furnace. The gas mains for delivery of hot or raw gas must be large in diameter and lined with fire brick. The accumulated lamp black and heavy pitch must be burned out of these mains at least once every week. For this reason, hot gas has a very limited application and is most commonly used only in connection with large furnaces, such as open hearths, soaking pits, glass melting tanks, brick kilns, lime kilns, etc., where the producer can be located close to the furnace. It is impracticable to distribute this raw gas thru any extensive gas distributing system.

Clean, cold producer gas is made up of the same constituents as raw gas, except that it is subjected to a cleaning process which reduces the temperature to about that of the surrounding atmosphere and at the same time, tar and lamp black are removed.

Clean producer gas for heat treating has many advantages, some of which are:

First: It may be made from anthracite, coke, charcoal, bituminous coal and lignite, our most abundant fuels.

Second: When cleaned it may be distributed in the same manner as natural or city gas.

Third: It makes possible the centralization of the coal and ash handling equipment.

Fourth: Within the ordinary range of oxidizing or reducing furnace conditions clean producer gas burns with a smokeless flame.

Fifth: It has proven successful in many applications to furnace work, not only from the standpoint of economies, but from the standpoint of better product.

Sixth: No method of furnace heating is so easy to control when properly installed as clean producer gas.

A clean gas plant can be located at any point on the owner's premises that is convenient for the handling of coal and ash and the gas may be distributed thru common steel pipe and fittings to any department of the works where fuel is required in just the same manner as natural gas or city gas is distributed.

The field for clean producer gas seems at this time to be unlimited, as may be noted by the fact that it has been used in the baking of breakfast foods, roasting coffee and other baking operations in the food industry, for core oven and mould drying in the foundry, for japanning, lead melting, soldering, brazing, heat treating, forging, box pile welding, rolling mills, etc., in the metal industry, for glass melting and glass annealing in the glass industry and for many applications in the chemical industry. Clean gas is also being used to mix with natural gas for distribution to domestic and industrial consumers in one of our largest cities.

Owing to the fact that many early installations of clean producer

gas were not equipped with a meter, it has been difficult to obtain exact figures, but the following comparison indicates the possibilities of producer gas:

One of our large automobile manufacturers has now installed clean producer gas equipment having a combined capacity of 50,000,000 cubic feet per 24 hours, with additional equipment now in the course of installation that will double this capacity. At this plant clean gas has proven an ideal fuel for all types of heat treating furnaces. It burns with a clear blue flame, giving a furnace atmosphere that is transparent, and even when working with a reducing flame, it does not smoke. The furnace rooms are much cleaner than where oil is used. It is uniform in quality and pressure and anyone familiar with the use of gas of any kind for furnace work realizes the value of uniformity of both quality and pressure for keeping temperatures and furnace atmospheres constant. The producer gas flame is soft and penetrating, whereas the oil flame is harsh and cutting. This feature has increased the life of the furnace linings and reduced the cost of furnace repairs. Packing boxes last longer, reducing the cost for renewals.

It is claimed by one foreman of the heat treat department where producer gas was used to replace oil that with gas he increased the output of his furnaces by one-third and handled his output with two-thirds the labor. Another has claimed and sent in records showing double the output on an annealing furnace with gas compared with oil. A careful study of gas application may give such a result, if the oil installation was poorly made, and there are many such installations. In no case is it necessary with producer gas to countenance a decrease in output and most of the data secured insures an increase.

The following data is taken from a comparative test report made by the engineers of an automobile manufacturer covering the use of producer gas and fuel oil in a heat treating furnace.

FURNACE—Furnaces of the underfired type, size of hearth 66″ x 56″ x 16″ high to crown of arch, 9″ walls, combustion chamber underneath divided in middle by 9″ wall with two burners in each chamber located at opposite ends. No change made in furnace for making comparative test except to change the burner. Standard make of burner used for oil test. "Self induction burner" designed for producer gas was used in the gas test with broken firebrick placed in front of each burner.

OIL USED—The western variety of fuel oil containing 18,000 B. T. U. per pound or 140,045 B. T. U. per gallon under a pressure of 40 pounds per square inch. Air for oil burner at 1 pound pressure. Oil temperature at burner 67° Fahr., air temperature at burner 79° Fahr.

GAS USED—Clean, cold producer gas temperature at burner 109° F., B. T. U. value 165 per cu. ft. Pressure at burner 1.9 inches mercury.

PREPARATION FOR TEST—Careful and complete precautions were taken for measuring the oil and metering the gas. Six consecutive runs were made to assure accuracy with a difference of only .6% between any two runs. The barometric pressure, temperature, density and calorific values were observed and used in checking results.

MATERIAL TREATED—Steel gear blanks in a flat ring weight 8 pounds each; thickest part of metal 1″. Furnace charge consisted of 131 pieces as above with a total weight of 1,048 pounds. Temperature of material when charged 60° F.

THE TEST—In each test for gas and oil the cycle started by putting the metal in the furnace and closing the door. The temperature of the

furnace was then brought up to 1560° Fahr., which required about 35 minutes. This temperature was then held constant for one hour, making the total elapsed time one hour and thirty-five minutes. The charge was then raked out. The average time to bring the batch up to heat using oil was 39 minutes; when using gas was 35½ minutes.

RESULTS OF TEST USING FUEL OIL

To bring up to heat	9.3333 gal.	or	1,307,087 B. T. U.
To hold temperature	7.1692 gal.	or	1,004,110 B. T. U.
Total	16.5025 gal.	or	2,411,197 B. T. U.

RESULTS WITH GAS

To bring to heat	5,005 cu. ft. at 165 B. T. U.	or	825,825 B. T. U.
To hold temp...	3,390 cu. ft. at 165 B. T. U.	or	559,350 B. T. U.
Total	8,395 cu. ft. at 165 B. T. U.	or	1,385,175 B. T. U.

The heat absorbed by the steel in raising it from 60° Fahr. to 1560° Fahr. would be approximately 258.4 B. T. U. per pound using .17226 for their specific heat. Considering only the heat input into the furnace during the "bringing to heat" period it required an input of 1,247 B. T. U. of oil per pound of metal. Under the same conditions using gas the heat input to the furnace was 788 B. T. U. per pound of metal.

In a subsequent run made with 1,360 pounds of the same stock and using gas it required a heat input of 670 B. T. U. per pound of metal.

It is very interesting to note that the total B. T. U. required for the one hour and 35 minutes was less when using gas than when using oil. If we assume that the coal used in the producer contains 13,000 B. T. U. per pound and a producer efficiency of 70% it required 152 pounds of coal fired to the producer to obtain this result with producer gas. Another comparison is that 9.2 pounds of coal fired to the producer did the work of one gallon of fuel oil fired to the furnace or seven pounds of steel were heated per pound of coal.

Another test was made on a battery of twelve large continuous carbonizing furnaces of the inclined type set on a platform 4′ above the floor and had three race-ways for the carbonizing pots.

The material treated consisted of six-steel ring-type gears about 9″ in diameter packed in a round container having a central tube. This container completely assembled for the furnace weighed about 119 pounds. Each gear weighed about 6 pounds. There were over fifty of these containers in the furnace at one time. The temperature of this furnace was 1750° Fahr. The material was held to heat in this furnace for five hours and forty minutes. Pressure air and gas at about 21″ of water were used without any pre-heat. The B. T. U. value of the gas was 177 on the three days on which these tests were made. In the process of carbonizing these steel gears three pots were pulled every twenty minutes and three pots added with a pushing device at the top of the incline. The fuel oil used per hour on these furnaces was 184 gallons. The cold, clean producer gas used per hour under same condition was 131,000 cu. ft. The temperature of the oil going into the furnace was 68° Fahr. and the gas tempera-

ture was 102° Fahr. The fuel cost per piece on producer gas was a trifle over 1c and as near as could be arrived at the cost per piece using fuel oil was about 2.1c.

Observations were taken on the deterioration of the combustion chambers under the two fuels. The oil gave a localized heat and the flame contact under pressure gradually broke down the supporting fire brick underneath the slide, necessitating rebuilding within six months. The deterioration with the gas was not 15% of that of oil.

When carbonizing with oil 184 gallons were used per hour. With producer gas, 2,500 pounds of coal per hour fired to the producer did the same work. In this instance 13½ pounds of coal was found to do the work of one gallon of oil. It is evident that the carbonizing furnace was better adapted to the use of oil fuel than the heat treat furnace referred to in the previous test. This is accounted for by the fact that the combustion chamber under the carbonizing furnace is large, allowing for more complete combustion of the fuel oil before passing into the heating chamber.

Three essential features stand out prominently in these tests. First, the use of gas showed considerable economy over fuel oil. Second, there was a great improvement in conditions around the furnace when gas was used. Third, producer gas should not be compared with oil on a B. T. U. basis only, but in connection with the furnace design and nature of the work to be done.

Clean producer gas can usually be applied to any ordinary heat treating furnace by simply changing the burner. Mechanical types of burners will show added economy and the use of recuperators or regenerators will also effect a substantial saving in fuel, but these while desirable are not necessary for operating success.

Clean producer gas as an industrial fuel is becoming more popular every year. It is now being used by industrial leaders such as the Crucible Steel Co., the Halcomb Steel Co., the Aluminum Co. of America, the Hazel-Atlas Glass Co., Ford Motor Co., A. O. Smith Co., Jeffrey Mfg. Co., Delco Division of General Motors Co., Robbins & Myers Co. and many others in similar lines of industry. These few are mentioned to illustrate the broad application of this unparalleled method of using coal as an industrial fuel.

The generation of large volumes of clean producer gas or the central fuel conditioning plants for large industrial applications was made possible by the development of a new and simple process of cleaning the gas. By this method as now improved it is possible to remove 99½% of the tar from the gas. Time and experience has thoroly demonstrated this system as an efficient, dependable and economical source of fuel supply. The objectionable features which are inherent in any extensive new system have been eliminated so that today a very satisfactory commercial installation can be made where exacting conditions and economy are desired.

In closing it may be well to state that too little time has been given from a metallurgical standpoint to the actual effect of different fuels on various steel products, and little if any thought given to the most efficient methods of applying fuel to furnace work. We must spend more time and study on these problems and surely one solution is clean producer gas.

DENDRITIC STEEL

H. G. Carter*

A Paper Presented Before the Milwaukee Chapter

Dendrites are many times called by other names, such as, "pine trees" and "cores." Possibly you are more familiar with the terms "pine tree structure" and "cored structure" than with "dendritic structure." However, in crystallography, the structure is indicated by the term "dendrite," for this reason I shall use the crystallographic term "dendrite."

Fig. 1 shows the iron-carbon diagram; let us consider the manner in which steel solidifies. Above the line AG, the liquidus, the steel is entirely liquid; below the line AFG, the solidus, the steel is entirely solid; in between these lines the steel is partly liquid and partly solid. It is here that we are interested, for it is during the solidification period that dendrites form.

Let us see how the phase rule applies to steel. The phase rule may be expressed by the formula

$$F = C - P + 2$$

where F is the number of degrees of freedom, C is the number of components, P is the number of phases and the 2 represents temperature and pressure. If we consider that the pressure is atmospheric, it will remain practically constant, and therefore, may be neglected, making the formula

$$F = C - P + 1.$$

The degrees of freedom are temperature and concentration, as we have considered the pressure constant or fixed. In steel the number of components are two, iron and carbon (neglecting the small amounts of Mn, Si, S, P, also the special alloying elements put in the alloy steels). The phases are liquid iron, liquid Fe_3C, solid solution of Fe_3C in gamma iron (austenite), solid beta iron, solid alpha iron, solid solution of Fe_3C in beta iron (martensite), solid cementite, and possibly others.

Above the liquidus there is only one phase, liquid, hence the system is bivariant, and can change over a wide range of temperature and concentration of Fe_3C in iron and still be liquid. I have neglected the gas phase because the vapor pressure of liquid steel in the range of temperatures in which we are interested is very small.

Below the solidus and above the critical range there is only one phase, solid solution of Fe_3C in gamma iron. The system is therefore bivariant similar to that above the liquidus.

Between the liquidus and the solidus we have two phases, liquid and solid, therefore the system becomes univariant. The variable being temperature; if we fix the temperature everything is fixed.

We may express the phase rule a little differently by the formula, potential energy of the liquid = the potential energy of the solid + heat lost or gained. By heat lost or gained, or in scientific terms, the latent heat of fusion, I mean the heat that is given off on cooling or absorbed on heating. A change in temperature means that there must be a change in the potential energies, that is, a change in the relative amounts of liquid and solid phases.

To illustrate, if we add heat, some of the solid melts; if we remove

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heat, some of the liquid freezes. Therefore with each slight drop in temperature crystals are deposited until all of the liquid has frozen. However during the solidification period the rate of cooling is much slower than while the temperature is above the liquidus or below the solidus, due to the liberation of heat with the change of state.

Refer now to the diagram, Fig. 1. When the metal cools to temperature indicated by A, pure iron starts to freeze at various places along the outer surface of the casting. As the octahedron is the crystallographic form in which iron and steel solidify, the pure iron freezes along the three axes of the octahedron.

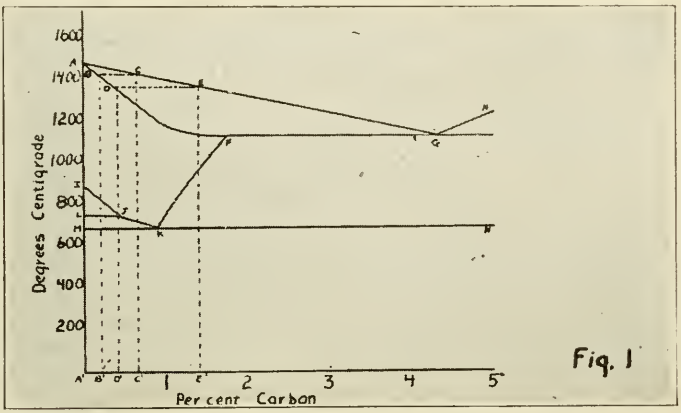

Fig. 1. Iron-Carbon diagram.

Now let us suppose the temperature has fallen very slightly, say to B on the diagram. An alloy A′B′ Fe_3C and iron freezes as a layer on the first octahedron, and adds another octahedron to the axes of the first (Fig. 2A). This layer is only slightly poorer in iron than the first crystal and contains a small amount of Fe_3C, the mother liquid becoming proportionately richer in the carbide and poorer in iron, and has a composition represented at C or A′C′, Fe_3C and iron.

Now let us suppose the temperature has fallen a little bit more, say to D on the diagram. An alloy A′D′ Fe_3C and iron freezes as a second layer on the first layer and adds another octahedron to the axes of the previous crystals (Fig. 2). This layer is poorer in iron and richer in carbide than the previous layer, and the mother liquid becomes correspondingly richer in carbide and poorer in iron.

At each slight drop in temperature, a layer deposits on the already frozen crystals, each successive layer becoming poorer and poorer in iron.

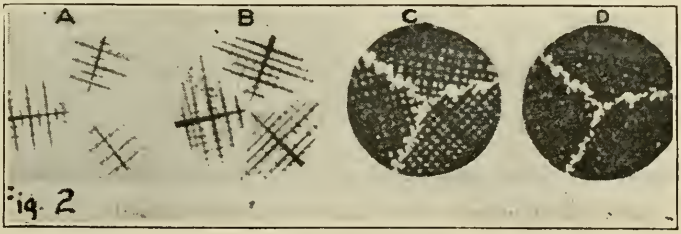

Fig. 2 Diagram showing manner steel freezes.

and richer and richer in carbide until the entire mass has frozen; at the same time the mother liquid becomes richer and richer in carbide and consequently poorer and poorer in iron.

The dendrite grows faster toward the center of the casting than sidewise, because the liquid at the center of the casting does not become exhausted of iron as fast as the liquid on the sides of the dendrites. Finally the dendrites become so large that their branches interlock, trapping any gas, slag, or other foreign material, and preventing their escape to the riser. If the metal was "wild" when poured, porous and dirty steel results.

The liquid last to freeze is rich in carbide, and if sulphur, phosphorus, and dirt is high it will be all, or nearly all, contained in this last metal to freeze, which is between the dendrites, or land locked by their branches (Figs. 3, 4, 7 and 9).

Just after the last drop has frozen, the dendrites will have a very heterogeneous structure with a chemical composition varying from pure iron at the center to high carbon exteriors. This non-uniformity results in a casting having very little ductility or power to resist repeated shock.

The crystallization taking place during the solidification period is called "primary crystallization." If during the process of solidification, the molten mother liquid is withdrawn, "isolated crystals" are exposed.

The question at once arises, since dendrites always form during solidification, why do we not always find them? The answer is that the carbon or the carbide, will diffuse in the solid state just below the solidus, if given sufficient time while the steel is hot enough; the rate of diffusion decreases very rapidly with a small drop in temperature.

Take the case of large castings such as ingots for example. The cooling of so large a mass is very slow, therefore both time and temperature are allowed for the diffusion to complete itself, in which case the interlocking branches of the dendrites form the grain boundaries of the austenitic grain. This period of diffusion is called "granulation." It really continues until the critical range is reached, at which time the steel is made up of a number of grains, each grain is built up of small octahedra, each having its own orientation. This structure we call austenite.

Such impurities as sulphur or sulphides, phosphorus, slags, etc., do not diffuse or at best extremely slowly, so that if the steel is not clean, these impurities are found segregated at the grain boundaries and are a source of trouble.

Austenite that has had its structure equalized (Fig. 5) responds to heat treatment readily (Fig. 6), but if its structure has not been equalized, it will not so respond.

Many of the readers doubtless have had tests fall down repeatedly even after several annealings and have wondered why, since as far as they knew the steel was satisfactory.

As Metallographist I have been at many of the foundries making small castings and have observed that in many cases the castings have been stripped very hot, not only red hot, but I have seen them practically white hot. The reason for this early stripping, so far as I could observe, was to get the castings out of the way so that the floor space could be cleaned up and the next set of molds gotten ready; in other words, trying to speed up production.

Our office has inspected castings which have failed badly in the ductility requirements; several reannealings seemed to make little or no

improvement and the castings were finally rejected (Table 1). On looking at the test bars under the microscope, beautiful examples of dendrites were found, even in the test bars which had received several annealings (Figs. 3 and 4). Some of the castings which behaved this way were known to have been stripped while very hot; the others were therefore presumed to have been treated in the same manner. We have found no such formation in test bars taken from castings known to have been cooled slowly, such as from large castings (Figs. 5 and 6), with the exception of castings which were very dirty. In these, remnants of the dendritic formation were seen, as shown by the segregated dirt, such as slag and sulphides. These impurities were found highly segregated in the grain boundaries, which I have just shown are the metal surrounding the dendrites just before the freezing is complete, and contain the trapped impurities.

The connection between early stripping and poor tests caused by dendrites finally dawned upon us, and it was decided to run an experiment to prove it. Accordingly we asked one of the foundries (at whose plant we were inspecting at the time) if they would help us run the experiment, which they did.

Two sets of test bars were cast in two separate flasks placed beside each other, and one was poured immediately after the other from the same metal. One set was shaken out of the sand as soon as the steel was thought to have set, e. g., five minutes after pouring; the other was left in the sand for twenty-four hours. The one shaken out in five minutes was white hot, and I doubt if the metal in its riser had completely set; the other was warm enough to be slightly uncomfortable to hold in the hand when shaken out. The sand used was their regular green molding sand, moistened the same as for their regular work.

Sections were cut from the test blocks and photographed as cast. Other sections were annealed by putting in a small electric furnace and heated (with the furnace) to 1850° F., held at 1850° F. for one hour, air cooled, reheated (with the furnace) to 1580° F., held one hour and cooled in the furnace (Figs. 7, 8, 9, 10).

The physical tests, unfortunately, gave negative results, as blowholds were encountered, which of course would give poor results. I shall, therefore, have to say, as the College Professor said, that this part of the experiment failed, but the principle remained just the same.

However, the experiment did not entirely fail as the micrographs indicate. It will be noticed that a very marked difference exists between the test stripped hot and the test cooled slowly. From this alone, it is evident that a marked difference in the physical properties would result.

The sections cut from the test bars stripped hot showed dendrites, while the sections cut from the test bars cooled slowly do not, but instead show the well known ingot structure. The heat treated bars also show a marked difference; the bar stripped hot is still very dendritic while that cooled slowly in the sand has its cast structure well broken up and a fine grained steel resulted.

Temperatures as high as 1850° F. are rarely used in annealing steel castings in as much as high and low temperature double heat treatments are seldom employed.

In this experiment the dendrites were not broken up by the double heat treatment, therefore, it is not surprising that in commercial practice where only one anneal is used and the temperature employed is two hun-

dred or more degrees Fahrenheit lower, that dendrites are still to be found and are troublesome.

The conclusion to be drawn from this experiment, together with many poor physical tests from bars taken from castings known to have been stripped very hot and whose structures were very dendritic, is that dendritic steel can not commercially, at least, be broken up structurally, therefore, to strip a casting while very hot gives rise to dendritic steel, while if the casting is allowed to cool slowly the dendrites will be broken up, and a structure results that will respond to heat treatment satisfactorily. In other words, stripping hot is very bad practice, and is inviting rejection of the castings due to the inability to meet the test requirements.

Table 1

Physical Tests

Fig. 3	37000	75000	11	12	course crystalline fracture
Fig. 4	39300	63000	9	10	course crystalline fracture
Fig. 6	38600	72800	27	43.4	silky ½ cup fracture

Table 2

Experimental Data

Fig. 7 Stripped after five minutes. Unannealed.
Fig. 8 Stripped after twenty-four hours. Unannealed.
Fig. 9 Stripped after five minutes. Heat treated.
Fig. 10 Stripped after twenty,-four hours. Heat treated.
Heat treatment. 1850° F-1-A, 1580° F-1-F.

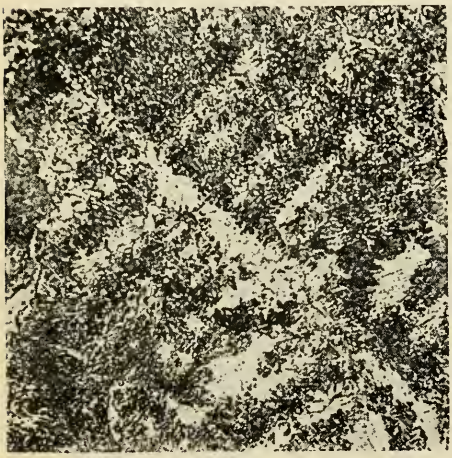

Fig. 3

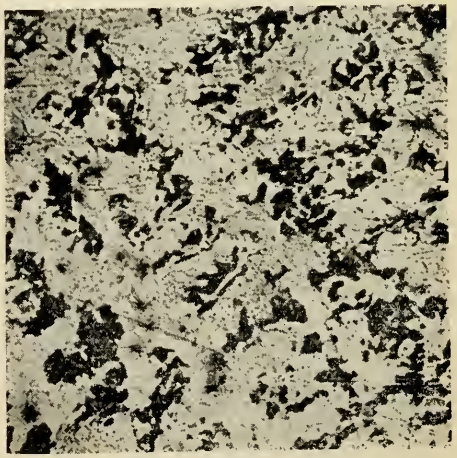

Fig. 4

Figs. 3 and 4. Dendrites found in small castings X100. Fig. 5. Unannealed structure from a large casting. Fig. 6. Annealed structure from a large casting. Figs. 5 and 6. X100.

Micrographs from experiment X100

Fig. 7. Test stripped in 5 min. unannealed. Fig. 8. Test cooled 24 hours, unannealed. Fig. 9. Test stripped in 5 min. heat treated. Fig. 10. Test cooled 24 hrs. heat treated. Heat treatment 1850° F-1-A. 1580° F-1-F.

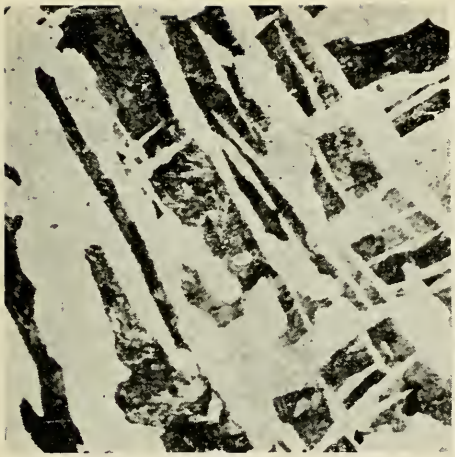

Fig. 5

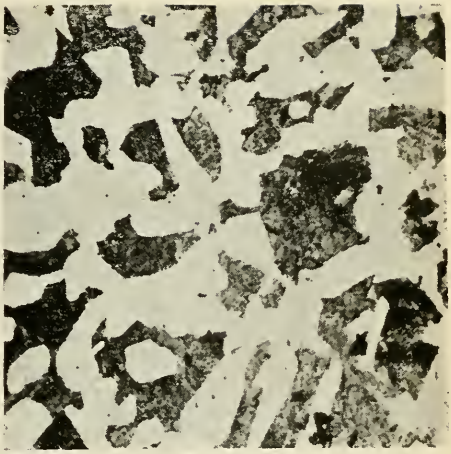

Fig. 6

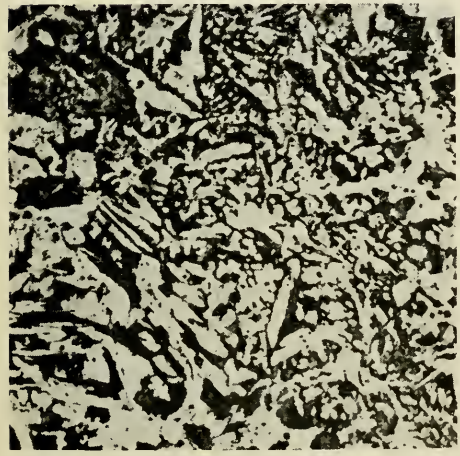

Fig. 7

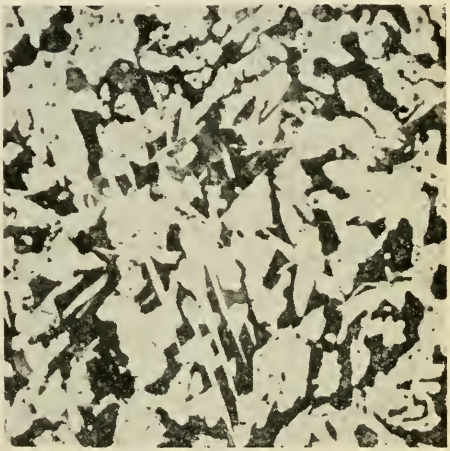

Fig. 8

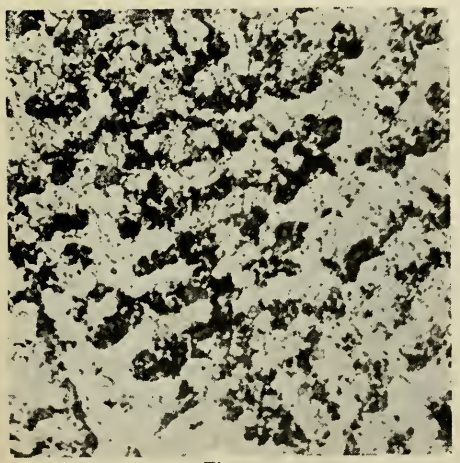

Fig. 9

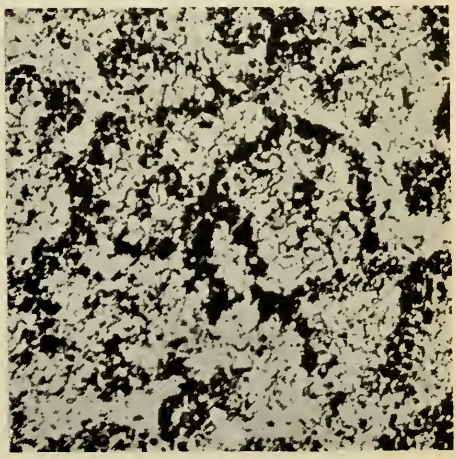

Fig. 10

A PROCESS FOR THE MANUFACTURE OF HELICAL SPRINGS FOR HEAVY DUTY

T. D. Lynch*

Read Before American Society for Steel Treating Convention, September, 1920

Springs of great variety of design and quality have been manufactured from flats, rods, ribbon and wire during the ages past. Some of them have been heat treated before forming, others after forming and still others have had no heat treatment, the high elastic properties being given to the latter by the work done in cold rolling or drawing the raw stock to its finished size.

Early spring making was for the use of buggies and spring wagons, then for clocks, watches, cars, locomotives, etc., and still later for automobiles. To the automobile manufacturer belongs the credit for the development of the superior quality of springs now used in the construction of automobiles. This progress, however, has not been without concentration of purpose relative to both material and treatment and each step has inscribed its mark of success or failure.

In this age of mechanical design, when every ounce of strength is exacted from each member, new problems arise continually in the use of springs demanding the highest quality possible to produce. To meet this growing demand for quality, every phase of spring manufacture must be coordinated and carefully processed at the furnace, at the rolling mill and at the spring making plant.

The steel maker has offered his carbon spring steel made in large open hearth furnaces, which has its field of application but is not strong enough for the most severe conditions that must be met at this time. Chrome vanadium steel, silico-manganese steel and chrome molybdenum steel have much higher elastic properties and are capable of withstanding proportionally greater stresses. Therefore, these and other alloy steels must be considered in connection with this high class work.

Within recent months one of the writer's duties has been to assist in the procurement of helical springs for a unique and unusually severe duty. The accompanying photograph shows the general problem involved, which consists in the transmission of the driving power of a motor to the wheels of a locomotive through a set of cushion springs. The arrangement is such as to permit free vertical and lateral wheel play. In this application the stresses are tension, compression, torsion and shear, separately or in combination, and these stresses are augmented from time to time by shock, producing a condition that makes necessary a material of high elastic strength, and, at the same time, a large degree of toughness.

The first step in the study of this problem was to investigate the general practice of spring makers—to find that the general process in vogue for the manufacture of springs from bars larger than ⅜ inch diameter is to obtain the bars from the steel maker, produced in large open hearth furnaces, rolled in a commercial manner, representing tonnage production. Bars thus made are heated to a temperature varying more or less from a bright to a dull red at different parts of their length, coiled into springs and quenched from this irregular coiling temperature. It is needless to say that springs made by such a process cannot be depended upon in severe service.

A few spring makers have realized the need for greater care in

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making and heat treating springs for heavy duty and a receptive attitude towards better spring making is now being taken by them.

Spring steel, and especially alloy spring steel, cannot be too carefully made, nor can it be too carefully coiled and treated in order to produce a strictly reliable finished product. Therefore, let us assume that the steel is carefully made and rolled into rods by the processes known to the steel makers as their best, coiled into springs at a proper and uniform temperature and finally treated by steel treaters represented at this meeting, under their best practice. I am sure you will vote with me in the affirmative that only such manufacture and treatment can be expected to give us the very best results. This hypothesis being granted, let us propose a process for your consideration, covering the manufacture of a silico-manganese steel spring made from 1 inch rounds, including the making and rolling of the steel and the coiling, treating, testing and inspection of the spring, in order that we may procure the reliable quality above indicated. There are many alloy spring steels on the market, any one of which would require similar care in their making and fabrication, but for this paper we have chosen a silico-manganese steel.

The question now arises how should a spring of the highest quality be processed, including the chemical composition, manufacture of the steel—rolling of the billets and bars—heating and coiling of the spring—the heat treating—inspection and general care required throughout the different steps in order to produce the most reliable product.

The following process has been worked out and is submitted for criticism and suggestions from others who may have similar problems to solve.

Chemical Analysis

The steel shall be what is known as silico-managanese steel of the following chemical analysis, both on ladle test and check test from finished rolled bars:

Carbon	.50—.60
Manganese	.60—.80
Phosphorus	not over .04
Sulphur	not over .04
Silicon	1.90—2.20

Manufacture of Steel

The steel shall be made by the crucible or electric furnace process and by a company that has been known to have produced high quality spring steel of the class specified.

The ingots shall be not less than 9″ square at large end and 8″ square at smaller end, so poured and the molds so coated as to give a smooth surface to the ingot.

Each ingot, when cold, shall be carefully inspected and any blemishes shall be chipped or ground out, leaving a surface that will be free from laps or seams after rolling.

Rolling of Rounds:

The ingots shall be slowly and carefully heated to approximately 1100 degrees Centigrade and rolled or forged to squares of approximately 3″ by 3″ and sheared into suitable billet lengths for final rolling. Excessive reduction will not be permitted.

Sufficient discard shall be made so that no signs of piping or segrega-

tion can be found when careful inspection is made, especially of the top cut.

The billets shall be allowed to become cold and a very careful inspection made for surface defects and any slight blemishes ground out, leaving a smooth, even surface, no ragged corners or slivers being permitted.

The billets shall then be heated to approximately 1100 degrees Centigrade and rolled to finish size, great care being taken to avoid excessive reduction at any one pass.

The bars shall be sheared to length and carefully inspected for piping, segregation and surface defects. Each bar shall be straight, free from surface cracks, scratches, seams, folds and indentations and shall be true to section. The diameter of the bar shall not vary more than two and one-half per cent from that specified.

Packing and Marking of Bars:

All bars shall be tied in bundles and a metal tag securely attached to each bundle. This tag shall have stamped on it the requisition number, heat number, size of rod and manufacturer's identification mark. When bundles are opened great care must be exercised so as not to nick or in any way injure the bars. A nick or scratch in a bar, however, small, can not be permitted.

Coiling of Springs

The bars shall be heated slowly to a uniform temperature of approximately 925 degrees C. (1700° F.) and immediately coiled over a mandrel preheated to at least 100 degrees C. The mandrel shall not be water cooled nor shall any water be allowed to touch the spring while hot.

Notching for length shall be done at a dull red heat and in such a manner as not to cut, scratch or otherwise injure the surface at any other point on the spring.

The springs after notching shall be allowed to cool slowly and uniformly in such a manner as to prevent local chilling which may cause surface stresses or cracks to form.

Treatment:

The springs shall be slowly and uniformly preheated to approximately 700° C. (1290° F.), transferred to a furnace held at a quenching temperature of 900° C. (1650° F.) and uniformly heated as near as possible to this temperature and quench in oil.

The quenched spring shall be drawn in a salt bath at approximately 455° C. (850° F.) to relieve quenching stresses.

The drawn springs shall be cleaned from the adhering salt by a hot soda wash, followed by an oil or lime dip to protect them from corrosion.

Physical Properties and Tests

The properties specified below shall be determined in the order given. The spring shall not be rapped or otherwise disturbed during the test.

(a) **Solid Height**—The solid height is the perpendicular distance between the plates of the testing machine when the spring is compressed solid with a test load of at least 125% of that necessary to bring all the coils in contact. The solid height shall not vary more than 1.5% from that specified.

(b) **Free Height**—The free height is the height of the spring when

the load specified in Paragraph (a) has been released, and is determined by placing a straight-edge across the top of the spring and measuring the perpendicular distance from the plate on which the spring stands to the straight edge, at the approximate center of the spring. The free height shall not vary more than 1.5% from that specified.

(c) **Loaded Height**—The loaded height is the distance between the plates of the testing machine when the specified working load is applied. The loaded height shall not vary more than 1.5% over nor more than .75% under that specified.

(d) **Permanent Set**—The permanent set is the difference, if any, between the free height and the height (measured at the same point and in a similar manner) after the spring has been compressed solid three times in rapid succession with the test load specified in Paragraph (a). The permanent set shall not exceed .4% of the free height.

(e) **Hardness Tests**—The Brinell hardness number shall not be less than 375 nor more than 450. This test shall be made on the coupon resulting from notching to length and broken off after spring has been heat treated.

(f) **Structure**—The grain structure of the finished spring should be troostitic or troosto-sorbitic.

Dimensions

The springs shall be straight, with uniform pitch, and shall remain straight throughout the working range.

The diameter of single coils of the spring shall confor mto the tolerance given on the drawing.

The concentricity of the coils of the spring shall be determined by means of a plug-gauge and ring-gauge, extending the full length of the spring and having the following dimensions:

	Length of Spring	
	10″ or less	Over 10″
Outside diameter of plug gauge....	d minus .063	d minus .094
Inside diameter of ring gauge.....	D plus .063	D plus .094

Where "d" is specified inside diameter of spring.

"D" is specified outside diameter of spring.

When the drawing specifies a spring with ends squared and the spring is placed with either end on a flat plate, its axis shall not make an angle of more than 5 degrees with a perpendicular to the plate.

Resetting of Spring

Springs varying from the required finished dimensions may be reheated and reset but all such reset springs shall be completely retreated —that is quenched and drawn again.

Packing and Marking

All springs shall be plainly marked with serial numbers and manufacturer's identification letter at one end of the finished spring and on each coupon resulting from notching to length. The purchaser shall assign the serial numbers to be used with each order.

Each size of spring shall be packed separately in such a manner as to protect the springs from injury during shipment.

Each package shall be plainly marked as follows:

Requisition number.

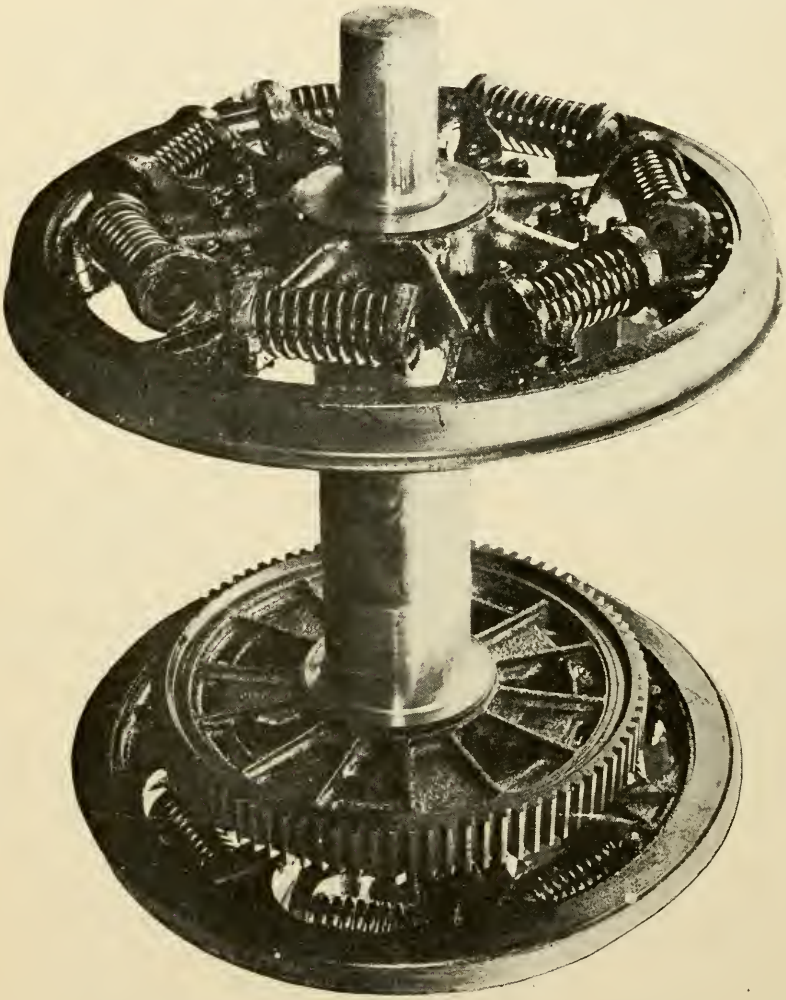
P. D. Spec. No.

Number of springs.

Style number of spring (or drawing and item number if there is no style number).

Name of manufacturer.

For example:—Req. C-5100; P. D. Spec. No. ; 6 springs; Style No. 591500; Blank Company.



Inspection

Tests and inspection shall be made by the purchaser at the place of manufacture prior to shipment.

The inspector representing the purchaser shall have free entry at all times while the contract of the purchaser is being performed, to all parts

of the manufacturer's works which concern the manufacture of the springs ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the springs are being furnished in accordance with this specification.

This paper has included more than the heat treatment of springs and is intended to emphasize the great importance of a better knowledge of complete spring manufacture and bring together on common terms the designing engineer, the steel maker and the spring maker.

A full discussion is desired, hoping that the combined experience of the members of this organization may bring out additional data that will assist in establishing a complete and efficient process for the manufacture of truly reliable springs for heavy duty. It is further hoped by the author to have shown the need of coordinating the talent and experience of the men at the steel mill, rolling mill and spring coiling plant as well as the heat treating and testing of the finished product.

STEEL FOR MACHINE PARTS

Stationary and Moving

Carbonized and Heat-Treated

Robert M. Taylor*

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There has not been much information published to indicate to machine tool builders what materials are generally used by the machine tool industries. In most cases a selection of material was made by conferring with the steel mill salesmen. This method may have its advantages, but it has resulted in the same material being called by many different names. When a buyer tried to buy a material from a different source it was a difficult task to juggle the trade names, analyses and physical specifications to get a comparison.

The automobile manufacturers met with the same difficulties, and early in their career they clearly saw the advisability of preparing uniform specifications and classifications for materials for their industry, and through the American Society of Automobile Engineers they developed the SAE specifications for steels.

These steels have been manufactured in large quantities, some steel mills make a specialty of them, and practically all steel mills manufacture them.

If the same or similar classification were adopted by other industries it would greatly simplify the difficulties of the buyers and steel manufacturers.

Right here it may be well to explain the SAE system of numbers.

The first figure indicates the class to which the steel belongs, thus 1 indicates a carbon steel, 2 nickel, 3 nickel chromium, 5 chromium, 6 chromium vanadian, 9 silico-manganese steels. In the case of the alloy steels the second figure generally indicates the approximate percentage of the predominant alloying element.

The last two or three figures indicate the average carbon content in "points" or hundredths of one percent, thus, 3120 indicates a nickel

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chromium steel with approximately 1 percent nickel (1.00% to 1.50%) and 20% carbon (15% to 25%). Also 1020 indicates no alloy, straight carbon approximately 20% carbon (15% to 25%).

After but little study it all appears very simple, easily remembered and to anyone using steels the number convey most of the information needed to understand the qualities or use of the steel.

The heat treatments have also been standardized and the letters designating the heat treatments used in this paper are the SAE standard.

When you speak of 6120 B to an automobile manufacturer he knows you mean a carbonized Chromium-Vanadium part.

I have prepared a chart arranged particularly for buyers, draughtsmen and shopmen of the machine tool industry, showing steels met with in machine tool plants.

The analyses are designated by SAE numbers, but they are screw stock, hub stock, machinery steel, spindle steel, tool steel, spring steel, etc., called by another name.

The analyses shown are typical SAE, but they correspond to the best grade of stock supplied to machine tool users under other names.

The physical properties given have been secured from the best information available, but are not the results of actual tests which I can substantiate. I give them to show comparative strengths rather than a basis for ordering material.

The first nine steels cover about all requirements of the ordinary machine shop. I give the others because of their growing use in extreme service.

The following explanation of applications of materials to major machine parts may be of some benefit to draughtsmen and shopmen.

Shafting: No. 1020 is usually used in cold rolled state. This same analysis is also frequently used in "Turned & Ground" state. The cold rolled has a disadvantage in some cases where long keyways are to be cut due to the fact that the keyway will relieve the surface tension and cause the shaft to buckle or become untrue.

No. 1045 can be used for shafting requiring greater strength. The same remark concerning finish of No. 1020 also applies to No. 1045.

Spindles: No. 1045 made by crucible process is most generally used. This material can be heat-treated to increase strength when desired. Treatments D, E or H being used.

No. 3135 made by open hearth process in such quantities as to insure uniformity has been very popular with concerns demanding a high grade alloy steel spindle. It has not been the practice to heat treat this material for ordinary spindles, but the material improves so much with heat treatment that it is advisable to heat treat in all cases, especially if there are any keyways or shoulders. Some concerns run the hardness up to 60 shore, and finish machine after heat treating, but in general practice 38 to 45 shore hardness is best because at greater hardness cutting is very difficult. Treatments D, E or H are used.

No. 6135 is used for spindles in extreme cases where vibration and alternate stresses are most severe. It should always be heat treated, either before, during or after machining. 38 to 45 shore hardness is the best hardness for spindle service. Treatments T or U are used.

Gears: For gears for low speed and light load material No. 1020 is used in soft state.

For gears for low speed and heavy load materials 1045 heat treatment H up to 65 shore hardness.

3135 heat treatment H up to 65 shore hardness.

6135 heat treatment T up to 65 shore hardness.

For gears for high speed and light load materials:

1020 treatment A or B up to 95 shore hardness.
3120 treatment G up to 95 shore hardness.
6120 treatment T up to 95 shore hardness.

For gears for high speed and heavy load materials:

3250 treatment M or Q 72 to 80 shore hardness.
6150 treatment U 72 to 80 shore hardness.
9260 treatment V 72 to 80 shore hardness.

Cams: Where no severe strains are imposed on light sections No. 1095 can be used, giving treatments F or X, shore hardness up to 90.

Where greater strength is required use No. 3250, treatment Q, shore hardness up to 85.

Where extreme hardness is required use:

5195 treatment Q up to 100 shore hardness.
6195 treatment U up to 100 shore hardness.
9260 treatment V up to 100 shore hardness.

Centers: No. 1095 is almost universally used heating head in lead pot and quenching in water. Treatment X, giving 90 to 100 shore hardness.

Lead Screws, etc.: No. 1135 X is a favorite for this use because of its free and smooth cutting properties.

Sometimes No. 1020 is used for such screws, but it is not advisable to do so except for extremely light duty. 1045 is better. Sulphur in this stock should not be below .03 or it will be difficult to get a smooth finish on the thread.

Thrust Washers: 1020 or 3120 carbonized treatment B are used for light service and 1095 treatment X, 3250 treatment Q, 5195 treatment R for heavy service.

Ball Races, Rollers & Pins: 5195 treatment R is a favorite for this service, 80 to 100 shore hardness.

Springs:

No. 1095 treatment F is generally used.
No. 6150 treatment U for severe service.
No. 9250 treatment V for severe service.
No. 9260 treatment V for severe service.

Keys: No. 1020 in cold rolled condition is frequently used, but is not recommended except where extremely low price is required.

No. 1045 is much preferred in a tempered condition because of its ability to resist distortion. When a key begins to rock the lower grade material will distort very quickly.

No. 3250 treatment M is used for sliding keys, etc., where a wear proof key with great strength is required.

Bolts, Nuts, Pins, Studs & Screws: No. 1114 is especially made to permit rapid screw machine production, with smooth finish, consideration of strength being secondary. This material can be carbonized by treatments A or B.

No. 1020 will give much greater strength both in soft and carbonized screws, carbonized by treatments A or B.

No. 1045 can be used for a tempered screw, treatment H.

Tool Post Screws, etc.: For screws of extreme strength No. 3120 or No. 3135 treatment H will give best results, hardness not above 65 shore.

HEAT TREATMENTS

Heat Treatment A

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650°-1750° F. desired).
2. Cool slowly or quench.
3. Reheat to 1450°-1500° F. and quench.

Heat Treatment B

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650°-1700° F. desired.)
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1550° to 1625° F.
4. Quench.
5. Reheat to 1400°-1450° F.
6. Quench.
7. Draw in hot oil at 300° to 450° F. depending upon the degree of hardness desired.

Heat Treatment D

After forging or machining:

1. Heat to 1500°-1600° F.
2. Quench.
3. Reheat to 1450°-1500° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

Heat Treatment E

After forging or machining:

1. Heat to 1500°-1550° F.
2. Cool slowly.
3. Reheat to 1450°-1550° F.
4. Quench.
5. Reheat to 600°-1200° F. and cool slowly.

Heat Treatment F

After shaping or coiling:

1. Heat to 1425°-1475° F.
2. Quench in oil.
3. Reheat to 400°-900° F., in accordance with temper desired, and cool slowly.

Heat Treatment G

After forging or machining:

1. Carbonize between 1600° F. and 1750° F. (1650-1700° F. desired.)
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1500°-1550° F.
4. Quench.
5. Reheat to 1300°-1400° F.
6. Quench.
7. Reheat to 250°-500° F. (in accordance with the necessities of the case, and cool slowly).

Heat Treatment H

After forging or machining:

1. Heat to 1500°-1600° F.
2. Quench.
3. Reheat to 600°-1200° F. and cool slowly.

Heat Treatment M

After forging or machining:

1. Heat to 1450°-1500° F.
2. Quench.
3. Reheat to 500°-1250° F. and cool slowly.

Heat Treatment P

After forging or machining:

1. Heat to 1450°-1500° F.
2. Quench.
3. Reheat to 1375°-1450° F.
4. Quench.
5. Reheat to 500°-1250° F. and cool slowly.

Heat Treatment Q

After forging:

1. Heat to 1475°-1525° F. (Hold at this temperature one-half hour, to insure thorough heating.)
2. Cool slowly.
3. Machine.
4. Reheat to 1375°-1425° F.
5. Quench.
6. Reheat to 250°-550° F. and cool slowly.

Heat Treatment R

After forging:

1. Heat to 1500°-1550° F.
2. Quench in oil.
3. Reheat to 1200°-1300° F. (Hold at this temperature three hours.)
4. Cool slowly.
5. Machine.
6. Reheat to 1350°-1450° F.
7. Quench in oil.
8. Reheat to 250°-500° F. and cool slowly.

Heat Treatment S

After forging or machining:

1. Carbonize at a temperature between 1600° F. and 1750° F. (1650°-1700° F. desired.)
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1650°-1750° F.
4. Quench.
5. Reheat to 1475°-1550° F.
6. Quench.
7. Reheat to 250°-550° F. and cool slowly.

Heat Treatment T

After forging or machining:

1. Heat to 1650°-1750° F.
2. Quench.
3. Reheat to 500°-1300° F., and cool slowly.

Heat Treatment U

After forging:

1. Heat to 1525°-1600° F. (Hold for about one-half hour.)
2. Cool slowly.
3. Machine.
4. Reheat to 1650°-1700° F.
5. Quench.
6. Reheat to 350°-550° F. and cool slowly.

Heat Treatment V

After forging or machining:

1. Heat to 1650°-1750°.
2. Quench.
3. Reheat to 400°-1200° F. and cool slowly.

Heat Treatment X

1. Heat to 1425°-1475° F.
2. Quench in water.
3. Reheat to 300°-600° F. and cool slowly.

CONCERNING PYROMETERS

Editor's Note.—The following graphically illustrated article, dealing with the "lag" of pyrometers under certain conditions, was taken from the "Heat Treatment Bulletin," published by Automatic and Electric Furnaces, Ltd., London, England. We venture to say that there are few users of pyrometers who can not profit by its perusal.—Editor.

Some persons swear by their pyrometers, some swear at them, and a good many prefer to ignore them. Unless one understands them, the last is probably the wisest course to pursue.

The chief causes of error in pyrometery are the following:

The indicator changes its calibration due to weakening of the permanent magnet.

The couple changes its constants due to a change in the alloy of which the wires are composed. This change as a rule does not seriously affect the readings until the alloy has oxidized till only a very fine thread remains. The remedy is to use a couple of two pure metals, or, if this is not practicable, use one wire of pure metal and one of alloy, arranging their respective diameters so that the wire of pure metal parts first.

Probably the greatest errors are, however, due to sluggishness of the couple. A couple composed of two thick wires inside a tube of silica is bound to be sluggish, as all heat has to be passed through the tube and at the same time the thick wire is rapidly conducting it away.

Some tests have been made for sluggishness which are decidedly illuminating. Two couples were made up—one was composed of wires .195 in. diameter, the other of wires of .036 in. diameter. Both were tested bare and again protected by a silica tube, the same tube being used in both cases.

The procedure was to immerse a couple in the furnace, which was maintained constant at 900 degrees, and then to note at one-minute intervals the reading of the indicator as the couple heated up. The indicator employed was a mirror instrument with a scale 5 ft. long, on which readings could be taken to one degree with certainty.

The readings obtained have been plotted as curves in Fig. 1, the ordinates being degrees Centigrade and the abscissae minutes from the moment of immersion of the couple in the furnace.

It will be seen that the smaller wire unprotected reaches five degrees short of its final temperature in the first minute and attains its full temperature in three minutes.

The larger wire takes five and a half minutes to reach within five degrees of its steady temperature.

When the couples are placed in silica, the small wire is ten degrees

short at the end of 14 minutes and is five degrees short of its final temperature at 18 minutes.

The larger wire when protected by a silica tube takes 34 minutes to attain to within 20 degrees and 50 minutes to reach ten degrees of the furnace temperature.

It will be seen, therefore, that a couple made of wire .195 in. diameter placed inside a silica tube is not likely to be of any utility except in exceptional cases, as it will always be lagging behind the changes in furnace temperature by quite a serious amount.

The moral is that bare couples should be employed wherever permissible, but should a protecting tube be necessary, the wire selected should be as small as possible in diameter.

Having decided in favor of small wires, the next point to consider is the material of which the wires are to be composed. The requirements are cheapness, long life, and high thermo-E.M.F.

Platinum and rhodium are expensive and only give a comparatively small voltage. What, then, can be done with base metals? Let us first consider the question of life.

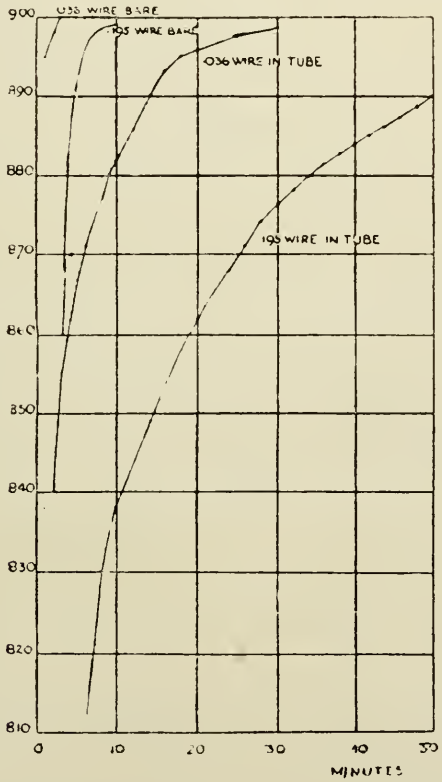

FIG. 1.

Five wires of the following materials, and all measuring about .036 in. diameter, were immersed in a furnace for two and a half hours standing at a temperature of approximately 1,000 degrees Centigrade. These wires were first gauged with a micrometer and afterwards were regauged.

the oxide having first been removed. The reduction of diameters found were as follows:

Eureka.....	.026	Nickel.....	.0015
Iron	.020	Nichrome.....	.001 or rather less.
Copper.....	.010		

These figures are not quite applicable to lower temperatures, as at 800 degrees Centigrade it is known that Eureka lasts rather longer than iron.

Clearly, a couple of Nichrome-Nickel is indicated as the best, provided that 1,000 degrees Centigrade is not to be exceeded, and provided, also, that this combination gives a good scale on the indicator.

In Fig. 2 is shown the calibration curves for five couples. The couples were tested in an oil bath against a thermometer, in freezing zinc, against the magnetic change point of iron, and against the melting point of copper.

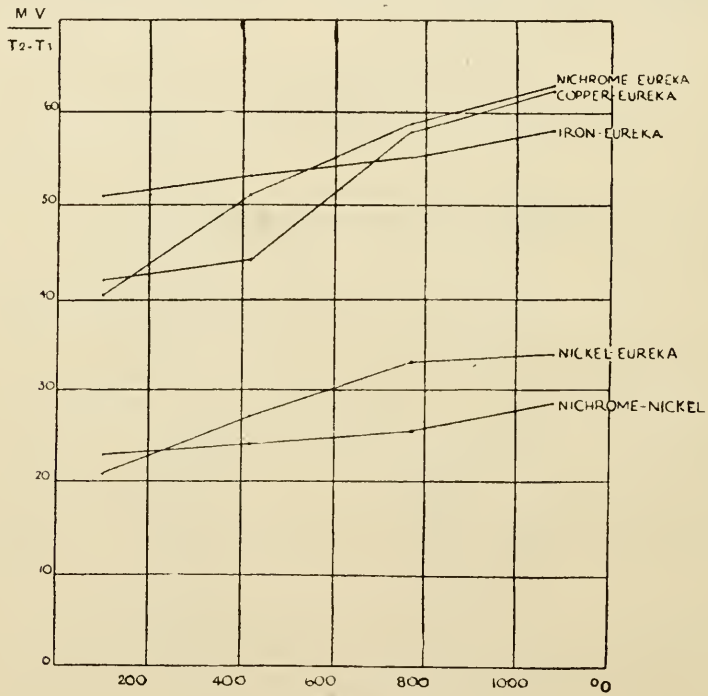

FIG 2.

The ordinates are scaled in micro-volts per degree of temperature difference between the hot and cold junctions and the abscissae are temperatures of the hot junctions.

Nichrome-Eureka gives the highest E.M.F. at the high temperatures. Iron-Eureka gives the most even scale. Copper-Eureka gives a very awkward scale, as there are two bends in it, necessitating testing at a greater number of points. Nichrome-Nickel unfortunately gives only about half the E.M.F. of Iron-Eureka. This would have, some years ago, necessitated the use of a suspended coil indicator, but of late years

instrument makers have so improved their pivoting that a pivotted coil instrument is now quite feasible.

In using alloys such as Nichrome or Eureka, it must be remembered that they cannot be relied upon to be always quite the same in composition. For example, two couples of Iron-Eureka, the Eureka being taken from different coils, have been found to differ in voltage by as much as ten per cent. Even on one coil it is quite usual to find differences of one per cent. Wherever a high degree of accuracy is required, it is necessary to test the couple with its own indicator throughout its working range.

For the majority of operations, however, it should be sufficient to supply each indicator and each couple with a batch number, it being understood that an indicator is only to be used with a couple bearing the same batch number as is marked on its scale.

RECENT PATENTS

1,340,913—May 25, 1920. METHOD OF AND MEANS FOR EXTENDING THE USABLE CONDITION OF METALLIC DIES AND TOOLS. Hellmuth Reinhardt Rosenbaum, of Brooklyn, New York. Specifications of Letters Patent. Application filed September 2, 1919. Serial No. 321,170. No drawing.

This invention relates to dies and tools made of steel and various steel alloys, and used for drop forgings, drawing, stamping, heading and otherwise shaping products of metal. These dies and tools are subjected to destructive wear by the shock, pressure, strain, etc., in the operation of the machines, in which they are used, and though made, as a rule, of the best quality of steel and steel alloys, the period of their usable condition is comparatively short. The object of my invention is to extend the period of their usable condition.

The efforts of producers of tool steels have been directed for many years to increase its toughness and otherwise improve its capacity to resist for a longer period the destructive effects, to which the dies for drop forgings, and tools for heading, drawing, etc., are exposed. My own researches and experiments were directed toward finding by what means, if any, the dies and tools made of the various steels, and steel alloys, may be maintained in usable condition for a longer period than heretofore. This led me to the discovery, that dies, punches and other similar tools for drop forging, heading and otherwise shaping of metallic parts, will, and do, withstand the destructive wear better, and for a much greater length of time, if they are artificially heated to, and kept heated while they are being used, at a temperature above their natural temperature and lower than that applied thereto in the hardening process. Roughly speaking this temperature at which the dies or tools are to be kept during their periods of active use varies from about 300 to about 1100° F., the degree of the temperature at which a die or tool is to be kept depending on the characteristics of the steel, or alloy, of which the die, tool, etc., is made. The tools or dies, made of some particularly compounded steels, and steel alloys, may have to be heated to, and kept at, a yet higher temperature than the maximum stated above, but the rule, that the temperature is to be somewhat lower than that to which the material (steel or alloy) of which the die, or tool is produced, must be heated in the hardening process, applies equally also to tools, or dies produced of these particularly compounded steels, or alloys.

To determine the temperature, which should, or may be, applied to a particular die or tool to attain the object of this invention, requires the

knowledge of the composition of the steel, or alloy, of which the die, or tool is made, or of the temperature to which it must be heated in hardening it. This information is readily obtainable from the maker of the steel or alloy, if not stated in the specifications, according to which the steel or alloy was produced. The examples here given are of steels and alloys generally known and now used for the enumerated and similar work.

Considering first the ordinary straight carbon tool steels, largely used for drop forging dies, *i.e.* steels, containing from 0.75 to 0.90% carbon, and which are heated to 1400-1475° F. for hardening and whose tempering heat does not exceed 750° F., a very high degree of toughness and resistant capacity is imparted to a die, or tool, produced of such a straight carbon steel, by heating it to, and keeping it while it is being used, at a temperature from about 400° to 600° F., the further rule being, in this instance, that the lighter the dropping weight of the machine, in which the die or tool is being used, or the lighter the stock and the easier the metal flows, of which the drop forging is to be produced, the nearer to the stated lower limit of the temperature the die may be heated and kept. I found also that it is preferable to heat and keep the tools or dies, made of straight carbon steels, at a lower temperature than tools or dies made of alloy steels, because the continuous application to the straight carbon tool steels of a temperature nearer to that to which they are heated in the hardening process will result in reducing their hardness.

Dies, or tools, made of steels alloyed with chrome nickel, carbon chromium, chrome vanadium, cobalt chromium, tungsten or molybdenum, will in some cases scarcely be affected by temperatures ranging up to 1100° F. This applies, for instance, to a tungsten high speed steel of approximately the following composition: C, 0.65; W, 16.00; Cr, 3.40; V, 0.80%. Tools, or dies, made of the so-called "tungsten high speed steel" of this or similar composition for heavy forging, trimming and blanking will stand a much longer service if heated to 1100° F., and kept at that temperature while they are being used. The period of their usable condition may be more than doubled thereby. Tools, or dies, made of cheaper grades of high speed steels, without any tungsten, for instance, a patented cobalt-chromium combination, containing about:—C, 1.50; Co, 3.25; Cr, 12.00; Mo, 0.75%, may be kept at a temperature of about 850° F. without losing the required degree of their hardness.

Dies for hydraulic bulldozing and compression work, as well as hot trimming and blanking, made of alloy steels containing approximately C, 0.45; W, 2.00; Cr, 1.00; Si, 0.80% if heated to about 500° F. and dies and tools for hot trimming, drop forging and hot or cold bolt heading, produced of steel containing about C, 0.90; Mn, 0.40; Cr, 3.50; Si, 0.20%, will have likewise their usable condition maintained for a much longer period if heated to about 750° F. and kept at that temperature while they are being used.

The heating of these tools and dies and maintaining them so heated while being used, may be effected in various ways. One method that I have found to serve well for all temperatures, and may be said to be perhaps the simplest and most inexpensive means, is to apply to the die, or tool, a jacket tightly packed with infusorial earth in a layer of suitable thickness, and then heating it by gas burners. In this way the die or tool will be heated uniformly, and then kept heated at, or very near, the requisite temperature, for many hours. Fine molding sand may be used instead of the infusorial earth. Or, any approved form of electrical heating apparatus may be employed.

Where it is more convenient, and the die or tool does not require to be heated above 600° F., an oil bath may take the place of the packing of infusorial earth; or a bath of molten lead or a combination of lead and tin may be used. In this connection it is well to note that a compound of 14 parts of lead with 8 parts of tin melts at about 420° F., and a combination of 38 parts of lead with 8 parts of tin at about 510° F., these temperatures being required more frequently, and the molten condition of these compounds serving to indicate the temperature of the die or tool.

The heating of the tool or die and the heat of the packing, or bath, are controlled by a suitable heat measuring instrument set in a recess in the die or tool, in the packing, or in the bath, and provision may be made for continuously indicating the temperature of the dies or tools by providing suitable temperature indicating instruments therefor.

I claim as my invention:

1. The method of extending the period of usable condition of a metallic die or tool, which consists in artificially heating the die or tool above the temperature naturally resulting from the use of the die or tool and below the temperature to which it was subjected in the hardening process, and keeping the die or tool at such temperature while it is being used.

2. The method of extending the period of usable condition of a metallic die or tool, which consists in artificially heating the die or tool to a temperature which will not impair its hardness but above the temperature naturally resulting from the use of the die or tool, and keeping the die or tool at such temperature while it is being used.

3. The combination with a metallic die, or tool, of means for heating it, and for keeping it so heated while the die, or tool, is being used.

The combination with a metallic die, or tool, of means for heating it and of a packing for keeping it heated while the die or tool is being used.

1,322,511—Nov. 25, 1919. STABLE-SURFACE ALLOY STEEL. Percy A. E. Armstrong, of Loudonville, New York. Specification of Letters Patent. Application filed May 24, 1919. Serial No. 299,636. No drawing.

This invention relates to an alloy steel containing iron, silicon, chromium and carbon, and of a highly stable character, that is to say, highly resistant to change or deterioration, such as produced in ordinary steel, for example, by staining, oxidizing, corroding and the like agents.

The base or principal portion of the alloy steel is iron, on which the material is largely dependent for strength and for cheapness.

One of the effects of chromium when alloyed with iron is, as has long been known, in the direction of making the material more stable, or resistant to deterioration, such as surface corrosion, but chromium, used substantially or entirely alone as an alloying material with iron, has several disadvantages. Chromium and iron do not alloy well together and a streaky and irregular effect is likely to be produced, articles made from the same melt often differing widely in their qualities. Iron-chromium alloys have a tendency toward red shortness with resulting cracks, blemishes and fissures, and scale badly when heated to temperatures required for hot mechanical work during commercial operations. The quantity of carbon which can be present in iron-chromium alloys without causing very substantial loss of surface stability or resistance to deterioration is quite limited. With my improved alloy steel, difficulties of this character are either absent or are reduced to the minimum.

Without being limited to any particular theory of the action of silicon in the alloy, I believe that the very excellent character of the material obtained by my invention may be accounted for by the formation of a silicid or silicids of iron, and of a silicid or silicids of chromium, which iron and chromium silicids are miscible with one another when molten. In any event, the silicon acts as a third alloy material which is highly beneficial in bringing about the formation of a substantially homogeneous alloy, free from troublesome streaks and irregularities, of high surface stability and readily workable. This beneficial action of silicon is not appreciable where it is present only in small proportions, say up to .30-.40%. To get such beneficial effects at least .50% of silicon must be present and more silicon is desirable. With the use of silicon as described herein, it becomes possible to have the ground mass of the material substantially solid solution. The more the ground mass is solid solution, the greater appears to be the stability of the alloy steel produced. With the silicon in the alloy steel, greater amounts of carbon can be used than would be available for production of stable surface material without a substantial proportion of silicon.

I believe that the action of carbon is one of fixing or, in other words, one of setting up a lag or retardation to change in the alloy steel during cooling, and further that the carbon enters into combination with the iron and chromium, which combinations, however, are modified by the action of the silicon present.

With my new alloy steel large numbers of small areas, of appearance similar to carbids in straight carbon steel, may be distinguished under the microscope and, while I have been unable to isolate same, I am inclined to consider them to be chromium carbids, though they may be mere concentrations of the ground mass fixed in their condition by carbon, or may be accounted for in yet other ways. They are not points of local attack, for on etching with aqua regia they are etched less than the ground mass, and no intensity of etching is discernible on the boundaries of these small areas. When present in the material either in the as cast or as rolled state, or subjected to prolonged heating and slow cooling, they do not adversely affect its surface stability.

Proportions given herein are by weight and it is to be noted that the atomic weight of silicon being only about half of that of chromium or iron, the percentages of this component, if stated by volume, would be about twice the figures given herein.

For production of stable surface material to be subjected to mechanical working, the silicon content may be from about .50% to 8%, and the chromium for about 3% to about 50%, and chromium and silicon, taken together from about 5% to about 58%. Mechanical workability becomes very slight as the extreme upper limits stated are approached, but with up to about 25-30% of chromium and about 5-6% of silicon the material can be hot forged reasonably well. The material just described may be cast, in fact, it usually is cast into ingots before being worked mechanically, and castings may be made therefrom if desired. For making castings, however, which are not to be mechanically worked, more silicon may be used up to about 30%, and chromium up to about 60%, or even higher.

The alloy steel having over about 5% and under about 13% silicon and chromium, taken together, is practically stainless and is resistant to corrosion and the like, when the ground mass is fixed solid solution by heat-treatment, but is more or less readily attacked by corroding and the like agents when not in such state. Heat-treatment is necessary with this

material in order to obtain solid solution ground mass. For production of such material the silicon may be from .5% to 7%, and chromium 3% to 10%, the proportions being distributed between the two so as to keep the totals between 5% and 13%. With such low proportions of silicon and chromium, taken together, the carbon should be kept low to get good results. Carbon as low as .05% may be used. Preferably the carbon should be kept under one-tenth of silicon and chromium, taken together. With an alloy steel containing silicon 2.5% and chromium 3%, for example, the carbon should preferably be under .55%, since, with such material, further increase of carbon, to say 1%, results in a considerable reduction of the desired surface stability in the alloy steel. Carbon .30%, for example, gives good results with these proportions of silicon and chromium, provided the ground mass is fixed solid solution by heat-treatment.

With chromium and silicon, taken together, over 13%, and chromium over 10%, the material is substantially solid solution in the ground mass and has high surface stability whether heat-treated or not. With such chromium and silicon, the carbon content may be increased, without substantially reducing the desirable qualities of the material, as, for example, with chromium about 10 to 20%, and silicon about 2% to 7%, it is sufficient, so long as a maximum of 3.5% carbon is not exceeded, to keep the carbon below one-sixth of silicon and chromium, taken together. For example, one very good alloy steel contains chromium 13.7%, silicon 3.2%, and carbon 2.56%. If more readily workable material is desired, low carbon down to about .05% may be used and in such case the silicon may be less, down to about .5%.

With chromium above about 20%, the presence of any considerable amount of carbon tends to make the material brittle and difficult to work, if the silicon is low. Such material is readily workable, however, if the silicon is more than twice the carbon, up to about 8% of silicon. For example, an alloy steel having chromium 22%, silicon 4.5%, and carbon 2.1% has high service stability and works well. As before, 3.5% carbon is about the maximum for mechanically workable material. Considerable relative reduction in carbon is permissible, if desired, as, for example, another good alloy steel contains chromium 31%, silicon 6.12%, and carbon .68%.

As already stated the alloy steel, when used for making castings not mechanically worked, may contain up to about 60% chromium, and up to about 30% silicon. The carbon in such cast material should preferably be less than one-half the silicon.

With the silicon-chromium content about 13% or over, the alloy is highly resistant to change or deterioration in the hot state. Cast into ingots it forges and rolls with very noticeable absence of mill scale, and when rolled down has practically nothing but a sort of brownish "rouge" on the surface, of extreme thinness. When exposed to an oxidizing atmosphere at about 1800° F. for over a month, a specimen containing about 12% chromium, 5% silicon and .45% carbon, showed no more than surface darkening. Alloy steel of this composition does not melt until heated to about 2600° F., and this specimen had a specific resistance of 115 microhms per cubic centimeter. Such material, and material having still higher silicon-chromium content is well adapted for electrical heating elements, particularly where run at high temperatures, which may be as great as 1800-2000° F. or even higher, the temperatures permissible depending to some extent, at least, upon the times they are maintained. For electrical heating elements where lower temperatures are sufficient, say 1300° F. or so, the material may have less silicon-chromium content, so long as silicon and chromium,

taken together, are over 5%. The specific resistance of an alloy steel of about this proportion is about 65 microhms. The specific resistance increases much more rapidly with increase of silicon than with increase of chromium. The cast material as well as the mechanically worked material may be made use of for electrical heating elements. When the production of electrical heating elements involves a drawing or bending operation the carbon should be kept low, for example, under 13% of chromium and silicon taken together, carbon may desirably be about .40% and for over 13% silicon-chromium content, carbon about 1% gives good results. Higher carbon may be used where heating elements are produced by casting or like operation or material cold bending is not involved.

In the production of my improved alloy steel, great practical advantage can be taken of the fact that silicon is present to a substantial extent in the alloy, along with chromium. The production of alloys containing chromium with little or no silicon requires ferro chromium of high purity, which is expensive to produce. I have found that silicon may be used as a good and inexpensive reducing agent in preparing the ferro-chromium for my alloy steel. Silicon, when used as a reducing agent, enters to a considerable extent into the molten metal as an alloy component, and in this way a ferro-chromium-silicon alloy may be cheaply and conveniently produced. The ferrous alloy so obtained, may be made use of directly in the melting furnace, with, of course, the addition of other materials for obtaining the proper proportions of the various alloy components, and various grades of ferro-chromium-silicon may be utilized by proper choice of other materials. In this way the process of manufacture is simplified and a considerable saving effected of valuable materials, including chromium and silicon. From 80% to nearly 100% of the silicon and practically all the chromium used in the melt can be gotten in the finished product, particularly when the melting is done in the electric furnace, which I consider the desirable apparatus for the purpose, though other systems of melting may be used, if desired, and materials from other sources may, of course, be used.

The known silicids, especially the chromium silicids, can be used to advantage as a ready guide to the production of good quality alloy steel and the nearer the composition is to that of the known silicids the better appears to be its surface stability.

My new material has quite distinctive cooling and heating curves, showing two marked transformation points or stages, the upper one of which tends to rise with increase of silicon and chromium content, or with increase of silicon content alone.

The material has a long plastic stage when melted and cast into an ingot or other mold; with small molds it readily solidifies into coherent ingots which can be worked to good advantage. When cast into larger molds the period of silidification is quite long unless provision is made for withdrawing the heat very rapidly. When means are not resorted to to keep down the time for solidification, the casting may be done by top pouring of the metal from the ladle with a considerable proportion of slag which forms a protecting envelope all around and over the molten metal, and can be readily knocked off when the ingot has been removed from the mold. Pouring rapidly as, for example, through a large nozzle, has been found to be of advantage in casting operations.

As an instance of the abnormal plastic stage or undercooling of my alloy, one batch of 5 tons containing about 17% chromium, about 4.5%

silicon and about .80% carbon which did not melt until it reached a temperature of about 2600° F., remained molten for considerably over an hour, and was still molten even when the temperature had fallen to below 2000° F. This long plastic stage has the valuable property of eliminating pipe in properly cast ingots or other castings to a very large degree and it is useful, particularly in making small castings, for readily producing castings of great soundness. The plastic stage is likewise quite long upon heating. This long plastic stage can be utilized to good advantage in making various articles and shapes from my new alloy steel, as, for example, it may be extruded or press or drop formed into pipes, bars and shapes of various kinds.

An important property of my new alloy steel is its high resistance to rapid heating or cooling. Placed in a furnace with a piece of ordinary carbon steel, for example, of like dimensions, it remains black for some time after the ordinary steel has been heated to a yellow heat. When made use of for gun linings and the like, where the surface is subjected to the action of nitrous vapors at extremely high temperatures for short periods, highly destructive of materials which heat and cool rapidly, this material gives extremely good results and is highly resistant to erosion. By reason of this same characteristic it is well adapted for a variety of important uses, such as annealing tubes, boxes and articles which are subjected to varying temperatures over long periods. This valuable property of slow heating enables the charge in the annealing boxes and the like to be more uniformly heated than is possible with the alloys or metals at present employed for such purposes.

My improved alloy has the important property of not being readily permeable to gases at high temperatures and is, therefore, well adapted for apparatus such as containers for highly heated gases being subjected to chemical reaction, and for use in tubes for protecting thermo couples of pyrometers, and the like, where it is important to shield highly heated metallic material from being corroded by attacking gases.

The new alloy material, especially when it contains above 13% silicon and chromium taken together, is not attacked or stained to any perceptible extent by nitric acid, nor by acetic or other organic acids, fruit juices and the like. It is attacked to some extent, however, by hydrochloric acid, sulfuric acid, and hydrofluoric acid, particularly when diluted.

My improved alloy steel, containing substantial proportions of silicon, has greater surface stability, that is to say, is much more resistant to stain, oxidation, corrosion and the like, than similar materials not containing a substantial proportion of silicon. Ingots and billets made from my alloy are worked with practically no formation of mill scale whatever, whereas material of analysis similar to my alloy steel, but containing no silicon more than a very small percentage, for instance, 3%, when heated for hot mechanical working, will scale very badly. So extremely resistant is my alloy steel to oxidation that when carbon analysis is being run, by passing oxygen thereover in presence of high heat, it has been found impossible to get the carbon out by combustion without the addition of oxid, such as lead oxid, so as to set up a chemical action upon the carbon, whereas with an alloy containing the same amount of chromium as my material, but with little or no silicon, an accurate determination of carbon by oxygen can be readily made without resort to use of foreign oxids or the like.

The alloy steel of my invention, within the ranges given for mechanical working above, can be readily worked and is not red short, and is

remarkably free from troublesome cracks, fissures, blemishes, and the like. As an instance of its remarkable freedom from surface seams, a 7 inch ingot heated to the necessary temperature for rolling, was cogged down in an 18 inch mill in the billet form, then reheated and rolled in a 9 inch bar mill down to a ½ inch round bar, and was entirely free from cracks, and seams of any sort. A 12 inch square ingot, cast with an envelop of slag, and containing chromium about 17%, silicon about 4.5% and carbon about .8% was forged under a steam hammer, cut into billets and rolled down to a 5/16 inch square bar, with similarly good results. Such goods results are very difficult to obtain, even from low carbon steel free from alloys, and impossible to obtain from stel containing any such percentage of chromium, with no more than .30% of silicon and with such higher carbon.

Some of the uses of my improved alloy material have already been referred to, including electrical heating units, castings, cutlery and tools, gun linings, annealing tubes, etc. My alloy steel is eminently suitable for a variety of other uses, including flat iron bases, laundry machinery, propellers, water pipes and pumps for fresh and salt water, for refrigerator pipes and fittings, and generally for apparatus, fittings, etc., which are exposed to heat, moisture, steam or intense cold; for apparatus and articles exposed to action of alkalis to which the alloy steel is highly resistant, also for objects exposed to the atmosphere, such as hinges, latches, and outside hardware generally, for electrical fittings, for power transmission, electric trolley or railroad service, particularly those parts that have to withstand electrolysis, balls for water valves, ball bearing balls and races for ball bearings which have to work under water, ship fittings, surgical instruments, dental tools, steel rules, articles for personal wear, such as jewelry settings, coins and medals, automatic stoker bars which have to withstand high temperatures, and very many other purposes where high resistance to stain, oxidation and corrosion are required. The alloy steel has low magnetic hysteresis and by suitable heat-treatment can be made substantially non magnetic. These qualities make it available for many additional uses, such as in scientific instruments, electrical meters and the like.

My improved alloy steel, of course, contains small percentages of metalloids, such as sulfur, prosphorous, arsenic, etc., and may contain variable percentages of metallic elements, substantially all of which can be employed, to some extent, at least. If the chromium-silicon content is high the quantity of metallic elements which may be present without substantial detriment to the surface stability of the alloy steel may be correspondingly increased. It is undesirable, ordinarily, to include any of these metallic elements in percentages over 1%, when the total chromium and silicon used is as low as 5%, but when 13% or more of chromium and silicon is used, other metallic elements can be incorporated up to a total of about 2% to 5% without substantial detriment to the valuable properties of my alloy steel. I may, for example, incorporate with the alloy steel having chromium-silicon content of 13% or over, as much as 4% of cobalt, or nickel, 1% of manganese, molybdenum, tungsten vanadium, titanium, zirconium, or other metals which form silicids or compounds or alloys with the iron, or chromium or both, or which do not materially effect the solid solution ground mass, with no considerable detriment resulting from their use.

1. An alloy steel of high surface stability containing chromium 3% to 50%, carbon .05% to 3.5% but not more than 1/10 of chromium and silicon taken together up to about 13% thereof and not more than 1/6 thereof above about 13%, silicon under 8%, over .5% and also over twice

the carbon, silicon and chromium together 5% to 58%, and the principal portion of the remainder iron.

2. An alloy steel of high surface stability containing chromium over 10%, carbon over .05% silicon over .5% chromium and silicon together over 13%, and the principal portion of the remainder iron.

3. An alloy steel of high surface stability containing chromium over 10%, carbon over .05%, silicon over .5% and also over twice the carbon, chromium and silicon together over 13%, and the principal portion of the remainder iron.

4. An alloy steel of high surface stability, containing chromium 10% to 20%, silicon .5% to .8%, chromium and silicon together 13% to 28%, carbon over .05%, under 3.5%, and also under 1/6 of chromium and silicon taken together, and the principal portion of the remainder iron.

5. An alloy steel of high surface stability, containing chromium over 10%, carbon over .05%, and more than twice as much silicon as carbon, and the principal portion of the remainder iron.

6. An alloy steel of high surface stability, containing chromium 3% to 50%, carbon .05% to 3.5%, silicon .5% to 8% and over twice the carbon, and the principal portion of the remainder iron.

7. A cast article of high surface stability composed of an alloy steel containing chromium 3% to 60%, carbon over .05% silicon .5% to 30% and more than twice the carbon, and the principal portion of the remainder iron.

MEMBERS, DID YOU RECEIVE YOUR COPY OF PROCEEDINGS, VOL. 2, NO. 13, ISSUED SEPT. 4, 1920?

"Inasmuch as there was an auto accident in transporting Vol. 2, No. 13, of the Proceedings of the past Steel Treating Research Society from the printers to the postoffice, about 200 copies of the Proceedings were destroyed. It is therefore impossible to determine which of our members did not receive this very interesting number, containing the papers of the "Symposium of Electric Heat-treating." If those members of the Society who did not receive their copy will mail a postal giving their name and correct present address to the Secretary's office, 208 N. Wabash Ave., Chicago, Ill., a copy of this issue will be cheerfully forwarded at once.

COMMERCIAL ITEMS

The Driver-Harris Co., Harrison, New Jersey, has issued 112 page booklet on the subject of Case Carbonizing. This booklet is well worth while and may be secured by addressing the company as above. The Introduction and table of contents are as follows:

INTRODUCTION TO CASE CARBONIZING

The rapid growth of the steel industry in the past thirty years has been reflected along all lines of metallurgical work.

The progress has been stimulated at every step by the scientific investigation of the problems involved. This scientific control has resulted in introducing economies in the operation of the older processes and in devising new methods for the attainment of new ends.

It is not surprising, then, to find that, in the field of "Case Carbonizing" or "Case Hardening," a large amount of information has been accumulated which is of value to the heat treater. It is no longer necessary to carry out the process of "Case Hardening" along purely empirical lines. The chemical reactions which are involved in the various methods used for "Case Hardening" are now well understood. The quality of the steel which should be used, the nature of the carbonizing compound, the temperature and time of the operation and the nature of the container have all been subject to investigation.

While this information is to be found in the scientific files, it frequently happens that it is not available to the heat treaters on whom devolves the practical application of the heat treating processes involved.

This booklet, then, aims to lay before the heat treater, in language which can be readily understood, the information which has been rendered available by the more recent scientific investigations.

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ANNUAL BANQUET GRAND BALL ROOM, BELLEVUE STRATFORD, THURSDAY EVENING, SEPT. 18.

President White: Men, it is with a great deal of pleasure this evening that all of us can be here in this room and join in our Second Annual Banquet. We know of no more fitting place for our convention at this particular period in our history than Philadelphia. It goes without saying that this is known as the "City of Brotherly Love." We know that in the early days it was in this city that the beginnings of our great country started. It is true that our Continental Congress met in other places than Philadelphia, preceding the Declaration of Independence, but at the same time that big move which made this nation and had its start began here, and in the same respect we feel that at this particular period in our history, when we are joining here as amalgamated societies under the name of the American Society for Steel Treating, we feel that it is fitting that we be here at this time.

Before going further it has been suggested that we ask the National Officers to stand, one at a time, so that you may all see them, and know that they are human. The first person we will ask to stand will be our First Vice President, Mr. T. E. Barker, of Chicago; Mr. T. D. Lynch, our Second Vice President, from Pittsburgh; Mr. William H. Eisenman, our National Secretary, a man without a home; Mr. William S. Bidle, our Treasurer, from Cleveland; Mr. Howard J. Stagg, our director, from Syracuse; Mr. Emil J. Janitzky, of Chicago; Mr. Walter C. Peterson, of Detroit; Mr. Frank P. Fahy, who has been appointed Director after we received, with regret, the resignation from the Board of Directors of Mr. MacFarland—Mr. Fahy, of New York.

All remain standing, amid applause from members.

I assure you, men, it is with great pleasure that I am able at this time to turn the meeting over to our worthy toastmaster, Mr. Joseph A. Steinmetz, who is president of the Aero Club of Pennsylvania, past president of the Engineers' Club, and in addition member of several technical and engineering societies. Major Steinmetz' forebears came over with William Penn on the good ship Welcome, so that it seems fitting that he should speak for the Philadelphia groups in extending welcome to the Steel Treaters of America. (Applause.)

Mr. Steinmetz: Mr. President, directors and guests, and members of your great society—coming down this evening from the house I met a friend and he asked me where I was going. I said, "Into town." He said, "Well, what are you going to do?" He isn't really inquisitive, but he asked me those questions tonight. I said, "I am going down to see the Steel Treaters." "Oh," he said, "I would like to go along." He thought it means something else, because he has nothing to do with the steel business. (Laughter.)

That brought very largely to mind something that I heard yesterday, and I had a good laugh over it. One fellow met another and said, "Well, old top, how is the world treating you?" Then in a sad and mournful voice he answered, "Very, very seldom."

Irrespective of the terrible shadow that the cloud has cast on the land, I think it is right, and I tell you it is a great pleasure and privilege to speak for our Philadelphia group and for the steel workers and for the steel treaters in that group with whom I have cast my lot, not by accident, but by deliberate intent, and that was some time ago—I had no idea, no dream

of what it meant, because today that is really only the great beginning of America in the steel arts. Your society is to be congratulated on the splendid exhibit you had this week. There were many exceedingly interesting and new things there in the alloys and above all in the stimulation and encouragement and gratification in what I see as the Sheffieldizing of America. There were finished things there that were new, and only the promise and only the finger index pointing to the tremendous tonnage of splendidly finished things that are to come, things well done, well handled, things well forged, and well fabricated and splendidly treated; things that will be unequaled in the arts and marts of the world. Welcome, then, to our city. Welcome from the groups that we know and from those that are not here, because on an occasion like this every Philadelphian stands firm together and welcomes the visitor within our gates. We wish that there were many things more that we could give to you, and many more courtesies we could extend to you. Our industries you know; we are a city of quality. I think by comparison to the finished tonnage—not, perhaps, to the basic or fundamental tonnage of the pig iron or the billet or the ore, but in the net finished result of the things that are well done and well worked out into finished and treated steels, Philadelphia stands without challenge. We make from the smallest needle to the heaviest and most ponderous locomotive. We are about to build one of the big bridges of the world across our Delaware, linking our sister state of New Jersey with Pennsylvania, giving quick access to our playground, the beaches of the Atlantic Coast, so that our men from the West and the far away may ride in unbroken journey to the bathing beaches. That great bridge of steel in the conferences only recently with the engineers that speak in terms that stagger me—they spoke boldly of steel treatments, of new alloys, and of new utensils that indicated a bridge of grace, and a bridge of fine, exquisite lines, and a bridge of extraordinary high tensile strength and a bridge of long, long life. We feel in Philadelphia that we are the iron gate of our state, leading open and outwards unbroken and untrammeled to the seven seas of the world. Our water course of the great Delaware leads away to all of the marts of trade and to all of the open ports where the finished product and the tonnage projects and products of our Western States and of our Central States go out through our gate. We are the iron gate of the finished industries. We are the iron gate of the steel fabricators and the steel makers.

There is one other thought before we introduce our speakers, and that is the tears and the horror and the unhappy, never-to-be-paid-for memories of the idle years when we sat unhappy and heart broken like nincompoops, told to be neutral in thought, deed and action. Those two terrible years are gone, but in the gaunt, terrible years that followed those three years of war and those four years when the millions of men were going down and the billions of treasure were being spent, we did what we could, and in that interval urged by the dire need and impelled by the gaunt spectre of war I think that in those four years more was done to awaken us, show us the leadership and show us the star of our future and of our hope, in our alloys, in our finished steels, metallurgies, fabrications, and output in the factory work than in any four lifetimes that had ever gone before.

Then we come quickly to the picture of those men that did it, those men who stand heroically before the nations of the world, as the men who did the great things, quietly, unobtrusively, many times sad heartedly, who worked in the alloys, who worked in the laboratories heroically through

night and through day, and who helped just as much as the fighting man, and to a degree I will not measure, and furnished him with the implements and tools of war. So it gives us an opportunity to introduce Dr. Albert Sauveur, the Professor of Metallurgy of Harvard University, whose subject is "Steel Wizards, Past and Present." (Applause.)

Dr. Sauveur's Address

Steel Wizards, Past and Present

Dr. Sauveur: Mr. Toastmaster, Members of the American Society for Steel Treating, Ladies and Gentlemen—Your president and toastmaster have shown good judgment, discretion and discrimination in selecting me as the first speaker and in keeping for the end the best they have to offer. It is fitting that we should begin with the lesser light, and finish by the brilliant flash lights that are to follow me.

I am also very glad to be the first speaker, because it relieves me from the necessity of trying to entertain you, feeling certain that the distinguished speakers that are to follow me will entertain you. It makes it easier for me to venture into a talk, which is not humorous, which some of you even might think depressing, feeling certain that the speakers who are to follow me will restore your cheerfulness.

When I had the honor to receive this invitation to speak, I was suggested because of my white hair that should be reminiscences. Now I dislike reminiscences; they are boring, and they give you the feeling that you belong to another generation; that you are a fossil, ready for the shelf. Instead I suggested as a title, rashly, perhaps, "Steel Wizards, Past and Present." Under the cloak of that title I am going to make an appeal for more important contribution on the part of American metallurgists and scientists to the art of making steel. We are rightly proud of our achievements, of our wonderful steel industry, of our country, of our leading position as the greatest iron and steel producing nation in the world, but, lest we forget what we owe to the steel wizards of other lands, it will be salutary to recall their deeds. It will keep us from too complacent an attitude towards other metallurgical nations reporting smaller tonnage production. It should stimulate in us a desire to contribute more substantially to the progress of the art in which we are interested.

We have been eminently successful. Our iron and steel industry has added vastly to the wealth of the nation. A book has been written entitled "The Romance of Steel," or "The Making of a Thousand Millionaires." Our business men, our captains of industry, our financial wizards have played their parts most successfully. Can the same tribute be paid to our scientific and technical wizards? Have they played their parts or have they been satisfied with following the tracks of wizards of other nations? Can they be accused of parasitic tendencies?

I should first describe what I have in mind by "steel wizards." I mean those men who have contributed the great basic invention upon which the iron and steel industry is founded. Men like Huntsmann, Cort, Reaumur, Bessemer, Abraham Darby, Tschernoff, Osmond, LeChatelier, Sorby, Howe; men whose discoveries, inventions or scientific contributions are epoch making.

Is it not true that, although being by far the greatest iron and steel producing country, we have not contributed our share of these great inventions, discoveries and scientific achievements? Is it not true that our

contributions have been chiefly of a mechanical kind, that they have consisted in the main in labor saving devices and machinery destined to cheapen and speed up productions. In this we have been undoubtedly successful and the importance of speeding up and cheapening production is not to be denied or belittled, but should we be satisfied with great advances in this direction only?

American mechanical wizards have passed through our steel plants, and have left their marks, but do we not look in vain for evidences of the passage of American metallurgical wizards?

Is it not true, and is not the thought somewhat humiliating, that if all the contributions of American metallurgists and scientists to the art of making steel had never been made, iron and steel would continue to be manufactured, worked and treated practically as they are today, in reduced proportions to be sure, but of unimpaired quality?

Is it not also true that if the contributions of English metallurgists and scientists were withdrawn, the entire structure of the iron and steel industry would ignominiously collapse? We would have neither puddling furnaces, nor crucible steel, nor Bessemer steel, nor open hearth steel, nor rolling or forging appliances.

We make more pig iron than any other country, but the blast furnace was neither invented nor developed in the United States. W have discarded the expensive fuel, charcoal, but this was first done by the Englishman, Dud Dudley, in 1619. We make more coke and use more coke for iron making than any other nation, but coke was first made and first used as a blast furnace fuel in England by Abraham Darby, who in 1735 had the inspiration of treating coal as the charcoal burners were treating wood, and this invaluable metallurgical fuel was his gift to the world.

More waste gases issue from our blast furnaces than in any other country and possibly we utilize it more thoroughly, but this has been made possible by the invention of metallurgists of other nations, by Aubertat in France, who in 1811 took a patent for the utilization of the waste gases. By James Beaumont Neilson, of Glasgow, who in 1828 first suggested the use of hot blast, by Faber du Four in France and James Palmer Budd in England, who in 1833 and 1845, respectively, suggested the heating of the blast by the burning of the waste gases; by Philip Taylor in England, who in 1840 suggested the closing of the top of the furnace that the waste gases might be collected, and G. Parry, of England, who in 1850 invented the bell and hopper or cup and cone as a means of closing the top of the furnace. By the Englishman, E. A. Cowper, who in 1860 introduced the use of regenerative brick stoves.

We have now, I believe, a greater number of gas blowing engines than any country, but the internal combustion engine using blast furnace gas was developed at Seraing in Belgium and we were at first quite reluctant to adopt it.

As notable improvements in blast furnace operations, we may claim, I believe, the automatic loading by skip cars and inclined planes and the double bell and hopper which that method requires.

We make more wrought iron than any other country, but the Reverberatory Puddling Furnace was invented in England in 1784 by Henry Cort and the Wet Puddling process introduced in that country also by James Hall and S. B. Rogers in about 1830.

We have a very important crucible steel industry, but crucible steel

was first made by an English clock maker, Huntsman, in 1740, while the method we follow by which we do away with the necessity of using blister or converted steel was introduced by the Englishman, Mushet, in 1801.

We are making more Bessemer steel than any other nation, but the Bessemer converter and its necessary equipment was invented in 1856 by the illustrious Bessemer, an Englishman of French parentage, and the Bessemer process made successful by Robert Forrester Musht, another Englishman, who discovered the necessity of adding Spiegeleisen or Manganese in some other form.

The basic Bessemer process in which, to be true, we are little interested, resulted from the masterly investigation and study of two Englishmen, Sidney Gilchrist Thomas and his cousin, Percy C. Gilchrist, in 1878.

We make more open hearth steel than any other country, but the regenerative furnace is not an American invention and open hearth steel was first made by the French metallurgist, Emile Martin, in 1865.

We are, if I am not mistaken, making more electric steel than any other country, but we took practically no part in the development of the electric furnace for steel making, the furnace we must use being the invention of the French metallurgist, Heroult.

We make more ferro alloys and more special or alloy steels than any other nation, but the most important of these, with the exception of high speed steel, we owe to the labor of metallurgists and scientists of other countries.

Our yearly tonnage of malleable castings is very much greater than that of any other nation, but the invention of the process is to be credited to the illustrious French chemist, Reaumur, who described it in 1722. To him also we owe the first scientific study and disclosure of the cementation and case hardening processes.

We roll and forge more steel than any other nation, but with the important exception of the three high rolling mill, rolling and forging appliances were not invented by us. The two high pull over grooved mill was invented by Cort; the reversing mill in 1866 by Ramsbatten in England; the universal mill is a German invention; the continuous mill was invented in 1861 by the Englishman, Charles White, although it has been much improved by the American engineers, Bedson and Morgan.

We owe the steam hammer to the genius of two Englishmen, James Watts and James Nasmyth, and the hydraulic presses to the Englishmen, Bessemer and Gledhill.

We heat treat a larger tonnage of steel than any other country, but can we claim that the scientific investigations which have lifted the art of treating steel to such high degree of perfection is due chiefly to American metallurgists and scientists? Is it not true that with the exception of the invaluable contributions of Professor Howe the work has been done chiefly in Russia by Tschernoff, in England by Sorby, Roberts, Austen, Arnold, Stead and Rosenhain, and in France by Osmond, LaChatelier, Guillet, Charpy, Portevin, Chevesnard and Grenet?

The discovery of high speed steel, or, if you prefer, of the treatment importing high speed properties to certain steels, by Taylor and Maunsel White, I am inclined to consider as our one epoch making contribution to the metallurgy of steel.

I am well aware that some have tried to throw doubts on the novelty of this discovery, but in my opinion their contentions are not only un-

generous, but unjustified. It continues to shine as the brightest American star of the metallurgical sky.

On the roll of honor for notable inventions, discoveries, or improvements in the art of making, working or heating iron and steel, or for notable and fruitful scientific contributions to that art, the following Americans are, I believe, entitled to a place:

Campbell, for designing the first tilting open hearth furnace.

John Fritz, for his invention of the three-high rolling mill.

James Gayley, for conceiving and executing the drying of the air blown in blast furnaces.

A. L. Holley, for notable improvements in the construction of Bessemer mills.

Henry Marion Howe, for his invaluable scientific contributions to our knowledge of steel.

W. R. Jones, for introducing the use of mixers in steel making.

Julian Kennedy, for notable improvements in the construction of blast furnaces and of blast furnace equipments.

F. W. Taylor and Maunsel White, for their epoch making discovery of high speed steel.

Samuel Thomas Wellman, for notable improvements in the construction of open hearth furnaces, for designing and construction charging machines and other useful appliances.

Frederick W. Wood, for his introduction of the car casting method for steel ingots.

The natural conclusion of my remarks must be a wish that we may become more prolific in steel wizards of the first order; that is, metallurgists who will not be satisfied in merely speeding up production through ingenius labor saving and other devices, but who will bend their energy and talent towards the discovery of new and epoch making methods of producing, working and treating steel that we may in future, as the leading metallurgical country, contribute our full share to metallurgical progress. Let me express the further wish that some of these steel wizards may be members of the American Society for Steel Treating; indeed, that some of them may be present in this hall tonight.

Now I don't like to leave you with these sobering thoughts in your mind. I know that the speakers that are following me will dispel those thoughts. At the same time I should like to help a little, and I don't like you to think because I am not entertaining you with stories that I cannot tell a story. But it is sometimes difficult to introduce a story in a graceful and fitting manner so as to connect it in a reasonable way with your talk. That was my topic. Fortunately I happened to mention to my distinguished colleague, Professor Richards, that I felt very nervous about talking to so large and imposing an assembly as this, and he said, "Well, don't be afraid; your Heavenly Father will watch you." And of course that gave me the connecting link, because it immediately brought to my mind this story:

Father and mother were traveling with little Johnnie in a sleeping car, and they put little Johnnie to bed and they said, "Johnnie, you must be very good; don't be afraid, your Heavenly Father will take care of you," but in the middle of the night little Johnnie got a little uneasy and he said, "Mother, are you there?" No answer. "Father, are you there?" No answer. And he repeated that question a few times until a grumpy old man in the next section got sort of peeved and he said, "Yes, father is here and

mother is here and Aunt Lucy is here and Cousin Lizzy is here, and now you go to sleep." And upon hearing the voice the little boy said to his mother, "Was that the voice of our Heavenly Father?"

Mr. Steinmetz: I think before introducing our next speaker it would be a splendid tribute and one quite worthy for the great Steel Treaters' Society of America to stand for a very brief moment in tribute and well wishes and hopes that that splendid, brave, indomitable and glorious little country of Belgium, the home of our speaker, comes back into industry, into the fullness of her life, into prosperity and happiness and peace forever. (Applause; then members stand for a moment in silent tribute.)

What Dr. Sauveur has said hits us. It hits us right fair and square, and it is good for us. In this room are the wizards of the present and of the past in the steels, and for one I am convinced that in a very short space of time we will be in a great group leadership in the steel working and fabricating and hardening and tempering and finishing arts, and in the steel making and in original discoveries. He harkens back to the time when we were a great rich, ample and virgin country, seemingly inexhaustible in supplies of coal, timber, oil fields, in almost everything. Naturally we wasted like pirates. We were tonnage people—that is all. It meant nothing to sweep away the forests of our nation. It means nothing to wreck in a generation the work of a thousand years. We are doing it yet, but we are learning a little bit. We think of China and her hundreds of thousands of square miles of yellow mud and the torrential rains running down over it; nothing but dirt and filth over that splendid, splendid land which was once a forest area. All that we are doing, and have done it boldly, and foolishly, and we didn't give a damn. We built then like giants, and we are doing that now, but the day is coming when we will have to polish like jewelers. The day is coming when we will have to watch the little economies. It is but natural, too, that we adopted the ideas and the practices of England. Why shouldn't we? He speaks of inventions way back in 1720. Why most of our forefathers were smiting Indians back in the woods in 1720. Of course, when the splendid men of England and France came here, they were the leaders in the arts they knew. Natural enough that they should bring with them the arts and the inventions, and the people came after them, and rightly and properly it was theirs, and we helped them. Perhaps we worked out there on the cinder pile some of those that are back there, and perhaps we had to learn. So our teachers did come from over there, and I hope the day is near when our teachers from here will go over there.

Our next speaker is a man whom I thank publicly and openly for many of the great inspirations of my life. He was my professor at Lehigh, and from him I learned of the metallurgies. He gave me the inspiration in the non-ferrous alloys, and many of the foundation stones are inscribed with the initials of Joseph W. Richards, professor in charge of the Department of Metallurgy, Lehigh University, and Secretary of the American Electro-Chemical Society. He will tell us of "The Ancient and Honorable Craft of Steel Treating." Dr. Richards. (Applause.)

Dr. Richards' Address

Ancient and Honorable Craft of Steel Treating

Dr. Richards: Mr. Toastmaster and Members of the American Society for Steel Treating, Ladies and Gentlemen: It is a great pleasure for me to meet you again, and I am going to take some of your time tonight

in connecting your society with the ancient and honorable art as it has existed for no one knows how long.

First, it is most honorable. There was once a painting here in Philadelphia, in the gallery of Mr. Harrison, within about two blocks of where we are sitting, painted by Schuessele, which showed King Solomon calling together the workers of his temple, intending to put in the seat of honor the most distinguished workman. He called together the workers in stone, in gold and silver, etc., and when they came into his presence one of them walked up to the chair and took it. He was the smith. Solomon said: "By what right do you take that chair?" "Well, he said to the stone mason, "Who made your tools?" "The blacksmith." He said to the worker in wood, "Who made your tools?" "The Blacksmith." And so he went through the whole row of them. When he got through he said to King Solomon, "All of these could do nothing if it hadn't been for me making

their tools." King Solomon recognized the force of the argument and said, "He is the chief craftsman of the builders of the temple." So you are the tool makers, and if anyone will stop to consider what the world would do without steel tools, he will get a faint idea of the usefulness of your profession.

Now, as to its antiquity. You will read in the books and encyclopedias that the age of gold was succeeded by the age of bronze and then the age of iron. I wish to tell you that I think that is wrong, although almost all of the books will tell it to you. The age of iron undoubtedly preceded the age of bronze, and the use of gold existed only where gold was abundant. In those countries where gold and copper occurred native (there are not many such places), they were used, but they were too soft to be of much use in building or in stone making and cutting, and undoubtedly the first metal that was made was iron. There is no doubt at all that the pyramids, with their huge stone slabs and blocks, were cut with iron tools.

You can go back of them thousands of years in the history of Nineveh and Assyria and find there that they must have known the metallurgy of iron. The making of iron is the oldest metallurgical art, and the treating of steel was coincident with it, because the first men who found iron very quickly made steel, and the treatment of steel was in all ages considered as part of the art of the worker in iron.

During the Middle Ages, when combat was almost man to man, a man's life depended on his sword and his armor, and the workers of steel were in the highest places. Their Guilds ruled very much as they pleased in some of those middle European cities, and the art of the smith, which was practically that of working in iron and steel, was considered one of the most honorable there was. I have a few notes here as to some of the restrictions which were placed on your predecessors of the tenth and the twelfth and the sixteenth centuries, and perhaps many of you have not heard them. I think they will interest you.

"Smiths were regarded in general as sorcerers and wise guys who were not afraid of Death and the Devil." That is a quotation from one of the old writers. "A boy, to be brought in as an apprentice to the smith, must be the legitimate son of honorable parents. No child of a night watchman, or a street musician, or a tower or gate watchman, a baker, a miller, a tanner, a linen weaver, a sheep herder, or a tax collector, could be a smith." (Laughter.) "The apprentice lad had to take the oath of secrecy and furnish about fifty to one hundred gulden as a bond to keep his oath." "He was first apprentice and could only become a master smith when he had produced a real masterpiece. Besides this he must pay when he became a master for a splendid dinner to the Guild and take a particular oath not to practice any sorcery, not to leave the country, not to divulge the secrets of the trade to any but his own son, or, having no son, to his nearest blood relation, and at the death of the master smith it was the custom to cremate his body and bury the ashes under the anvil in the smithy."

I will quote a few of the old recipes or saying as to how steel was treated and what it was. Said one old gentleman in 1540—(and I want you to notice what a good idea he had of steel): "Steel is nothing else but iron worked up with much art and much soaking in the fire until it is brought to a perfect mixture and given properties it did not before possess. Likewise, it may have taken up suitable materials of a dry or fatty tendency; also a certain moistness and hereby becomes white and denser. The long firing also opens up and softens its pores, which are drawn together again tightly by the power of the cold of the quenching water. The iron is thus given hardness, and the hardness makes it brittle. As iron can be made from any iron ore, likewise steel can be made from any pure iron."

That is 1540, when they were commencing to get some real ideas on steel. One of the first reliable books on the metallurgy of iron and steel was written by our friend, Swedenborg, the theologian.

Another says, "Steel is nobler than iron, and there are two kinds, the artificial and the natural. The natural is hard and more easily broken than iron." By natural he meant the steel made directly in the furnace from the ore. "The artificial is made of the hardest, purest iron, with limestone. The best shows a small white grain, does not rust, and has no cracks. To harden it properly clean it well and quench it three to four times when red hot in a mixture of three to four parts of radish juice and decoction of earth worms. It will then cut iron like lead." Earth worms seem to be a particular recipe of those old steel treaters.

Another one, named Nostradamus, said, "Distill earth worms with turnips and cucumber roots mixed in equal proportions. The iron is quenched in this distilled liquid. Repeat it if you want it harder."

Another German book said, "Macerate the leaves of laurel with the stems and sprouts, pass the juice through a linen cloth and keep it in a glass vessel; mix the juice with equal proportions of urine from a man and the juice of earthworms; dip the glowing iron in this mixture and keep it immersed until golden specks appear. To make the most desirable edges on swords and daggers, take a handful of soot, four ounces of linseed oil and decoction of earth worms, and boil it together; make the cutting edge red hot and quench in this liquid." (Laughter.)

Here is one gem which I'm going to read you unexpurgated. Theophilus Presbyter, a Benedictine monk, in the Twelfth century, says: "To harden iron this method is in use for tools to work glass and stone; take a three-year-old billy goat, tie him up three days without food; on the fourth day feed him ferns and nothing else; when he has lived on these two days, put him the following night into a vat or tub with holes in the bottom under which you put a sound bowl to collect his urine. After collecting this two or three nights, when you have enough, let the billy goat go, but harden the iron in his urine." (Laughter.) I am afraid you are learning some interesting recipes tonight.

In the Middle Ages, swords were some of the most precious belongings, and the swords of Damascus, Toledo and Japan were particularly valued. I have at home a Japanese sword about 450 years old, and this is the way in which it was made. A piece of iron about six inches long and two inches wide was taken and doubled over on itself, and then welded out until it was the original length. That operation of doubling it and welding it and working it out was repeated fifteen times. At the end of that time three pieces of similar size were thus worked in the same way. Those three pieces placed one on top of the other were then worked out into a bar six inches long, two inches wide, and that bar was again split in two and welded five times. With a skilled workman getting about twenty cents a day, that treatment did not cost much in those days, and you can figure out that there are about four million layers in that steel blade, and really I believe that this tremendous amount of working and those tremendous number of layers account in large measure for the beauty and the strength of those old swords. It is related of Richard Cour De Leon, the English King, that when he was in Palestine he had his big two-handled sword with him and Saladin, the Saracen Emperor, met him. They were bragging about their swords and Richard ordered them to put down an iron bar about an inch in diameter. He whirled his sword around his head and came down and cut that steel bar in two. Some feats of that sort were really done with those magnificent old two-edged swords about five feet long, with an immense handle for two hands. Saladin took out his curved scimitar and called an attendant, who threw a ladies' veil up into the air; Saladin cut it in two with his scimitar as it was floating in the air. Something like that can be done with those magnificent swords of Damascus.

The ancientness of your trade is something in which you take a second place to nobody. Perhaps the worker in wrought iron may claim to be the older of the two arts, but the worker in steel certainly followed him very closely, and in ancient times the two were one trade.

There is a piece of iron which has nickel in it and some carbon, which was found in the Pyramid of Cheops, and dates from about the year 3000 B. C., but that is comparatively modern. I am sure that, although we haven't the dates to give, that the metallurgy of iron and steel dates back thousands of years before that, and you are the present representatives of that ancient art, an art which passed through a great many vicissitudes. Those old workers certainly knew their trade as far as their capacities and the things at their command would allow it, but at the present time you have the great resources of the chemical and physical laboratories and modern methods which have been devised.

The Simplest Form of Pyrometer

I wish to close with a plea to you to use those facilities to the fullest extent. Most of you have seen, perhaps, that picture of the simplest form of pyrometer, the old man who opens a furnace door and looks in. Now it is only the simplest form of a steel treater that will allow his work to depend on that method of getting temperature. With the appliances now at our command it is possible for us to use scientific and exact methods instead of mere "rule of thumb," and to connect our practice with the accumulated experience of former ages.

You are the most ancient of metallurgical workers, and the most honorable. May I not plead with you to become the most scientific. (Applause.)

Mr. Steinmetz: I think Dr. Richards' definition of the ancient smith impresses us. I think to a degree it holds good today—"not afraid of fire or the Devil." I have been in many of the big forges in Pittsburgh and our district here when I want to tell you I was pretty well scared. I think the society undoubtedly will second his objection to the tax collectors, and I move that that holds forever good. They are getting too close to us now anyhow, and we don't want them in the steel business. I can see great improvements in the smaller and better finished articles in the treatments with radish juice and earth worms. That certainly sounds like one of the wartime specifications that we wrestled with. (Applause and laughter.) We all can learn something. We had during the stress and trials and tribulations of that interval here in Philadelphia a very thrilling lecture; it impressed me; I don't think anything has impressed me more than this lecture. It was a very direct hit at all of us. There were probably a thousand men present. The topic was "Are You a Nut or Are You a Rivet?" He worked it out splendidly. At first it rather hurt us, but he went on this theory, that a nut gets loose and it turns willy-nilly, and it wobbles and then lets go. Not so a rivet—well set, sturdy, positive and eternal. It

knows its job and it sticks. There is a whole lot in that. So we have as our next speaker a "Rivet," a man who knows what he is talking about. He is well set. There is no wobble about him. That man is Samuel M. Vauclain, president of the Baldwin Locomotive Works, and Mr. Vauclain will tell us of his impressions abroad. (Applause.)

Mr. Vauclain's Address

Impressions from Abroad

Mr. Vauclain: Mr. Toastmaster, Heat Treaters and Ladies—I am the last speaker. Probably if you are interested I will endeavor to fill in, and when anybody gets too full, if they will simply hold up their hands I will cease. I have been assigned a subject, "My Impressions Abroad."

Now, I had many impressions while I was abroad, perhaps some of them I would not care to mention here, but the principal impressions which I had when abroad no doubt may interest you, because they simply concerned business. Business that I was engaged in, business that you are all engaged in, and business that some of my Philadelphia friends are engaged in, who are not represented among the steel treaters.

In order to get a real impression abroad one must so travel that he can be impressed. Those who go abroad and simply inhabit the luxurious hotels which are to be found everywhere, even in the most devastated countries or so-called devastated countries of Europe, a proper conception of what Europe is today cannot be had. But fortunately, if you can afford to pay for the use of an auto, and endure the hardships which an auto trip through that country, if it is made in anything like American time, will cause you a correct impression, not only of the condition of the country, but a correct impression of the attitude of the people of those countries can be had.

Of course, to be perfectly impressed, one must have no pre-thought on the matter. He must not have arrived at a conclusion before he visits the country. He must be willing to judge the country as he sees it, to judge the people as he sees them, and in that way come back with profit, not only to himself, but to the people whom he represents.

Getting off the steamer in Cherbourg and taking an auto for Paris prepares one for what he is going to see as he travels on through Europe toward Russia.

The magnificent country, which probably was robbed of almost everything it had to support the armies in France, practically is a paradise. The people are contented, they are earnest in their work, they arise with the sun, and they go to bed when no longer they are able to see.

But the universal feeling of contentment which those people have in that section is simply nothing compared with the universal contentment and confidence in each other that is found among the people where war has been waged backwards and forwards for at least four or five years.

Leaving Paris, and Paris was just the same old Paris we knew before the war, very little difference excepting that the people were all more earnest, they were applying themselves to reconstruction, not the reconstruction of the devastated lands, but the reconstruction of their business to conform to the more serious requirements of the times to provide themselves with the wherewith to conduct a business when money was almost impossible to get, and where the rate of exchange had fallen to an unparalleled point. France demonstrated to me that, in a short few days before I left for the Far East, no one need to worry in America as to what would

become of France. France would take care of that herself, and in her own inimitable manner.

Taking an auto and going down through that part of France where war waged, one had greater confidence not only in Europe, but had greater confidence in the people of this world, in the human race, of their ability to survive almost any catastrophe which might happen to them.

Every field that a year before had been shot to pieces, that had been practically ruined, as we were told in this country, had been restored to its original beauty and efficiency.

The most beautiful country that man ever gazed upon, with buildings shattered and destroyed, whole towns removed, but every field and every roadway in perfect order, grain growing where but a year before shot and shell and barbed wire abounded, and not a single sad face, people in black who had lost members of their families near and dear to them, but I reasoned out that these people rejoiced and were glad that it had been no worse, and that there was at least something left them to begin life's work in this world with once more. People who had beautiful farm lands, beautiful vineyards perfectly kept, were perfectly happy to live in the cellar with a stove-pipe shoved up through the first floor, because the rest of the house had gone.

And it would require time, it would require some assistance, it would require some years of labor before another house could be built. But not one single complaint was made to me by anybody with whom I conversed throughout the devastated section of France, which I visited. Everywhere factories were beginning to run, the farms seemed to have been recovered and the factories were fast being put into the same condition.

Having a little business engagement with my bosom friends down in Poland, it became necessary to go to Warsaw. A trip to Warsaw eight months ago was an education because these new states were then endeavoring to get their borders in shape, their accustomed officers well stationed so that no guilty man could escape, that every person who wished to cross would have to be examined inside and out before he was permitted to pass. I made up my mind that the going might not be very good in that section of the country, and therefore I surprised the railroad people by hiring for my trip a whole passenger coach, a sleeping coach, which had some eight or ten staterooms in it, little bits of things, for my party. It was fortunate that I did so, because the occupancy of a car of this description through countries and over railroads where traveling is a real art, where standing room only is to be found, where every available square inch of the platform is occupied by those who are not fortunate enough to get into the cars, or be pulled through the windows and the roofs themselves are occupied, but the people don't mind that. They are glad that they are able to ride on the roof of a car, and they are not finding fault with their friends or their neighbors because they have not a Pullman berth to ride in. They will stand at a railroad station for three weeks, come every day for three weeks waiting for an opportunity for the single train which may move through the city to get on a car for standing room to the next station, and this cheerfully.

Now the impression made upon me by witnessing this devotion to their labors or their duties or their business or to their pleasures made me feel that if these people can be satisfied and happy and industrious under conditions of this kind, I had better get back to America and endeavor to

put the same thing in practice among those with whom I am associated, and who have the pleasure or difficulty of working for me.

Far off through Poland up to Danzig, which is a free state, the grim army of the British nation in full possession, splendid to look at, stern, with a German population staring them squarely in the face, Danzig is not a Polish country, it is a German state, a German city, and a German state. But under the British it is British, because it is under the British, the British appropriated a church and every man in the British army stationed there goes to church with his musket on his shoulder and his cartridges in his belt. It reminds me of our old time Puritanism in this country. You had to do it, and if you did not do it, if you were not good, you would be made to be good.

I find no difficulty there in getting along; I found the people determined to prosper under the situation. Their town had not been devastated in any manner, and therefore left it and left it with great pleasure, because I felt that I would get no further ideas there, that I had better penetrate farther on.

Arriving back in Warsaw I determined to go down through Galicia via Krakow, Lembourg, over to Chernovitz, and then down through Rumania to Bucharest. And unless you Americans who desire to find out the conditions in Europe make this trip you will never realize what the true conditions in those Balkan or border states has been, and is now, and will be for a long time.

But I also ask you not to worry. You don't need to worry about these people. They are perfectly able to take care of themselves. They have not the one one-hundredth of what we have to get along with, but they have something, and it is theirs, and they are making the best use of it, and they are going after this thing, Ladies and Gentlemen, in a manner that in a very few short years will put them well to the fore, and we Americans here, who are reveling in a prosperity few of us realize or recognize, will find it very difficult to compete with them in the markets of the world.

These are a great people, and they dress rather peculiarly. In Roumania we find the home of the slit skirt. We used to find fault with the ladies for having their skirts split up to the knee on the side, but a Roumanian woman in her native costume has a white petticoat, and her dress consists of two flaps, one in front, down to her shoe tops, and one down behind. The men are also distinguished for their apparel, and you can always tell when you see a Roumanian peasant at the railroad station or on the train riding with you. You can always tell to what extent he enjoys the affection of his life. Because they wear, contrary to our custom, their shirttails outside, whereas we wear ours inside, and those who are thought well of by their wives have their shirttails embroidered in the most beautiful manner. And therefore my impression was that if a man did not have—if his shirt-tail was plain, his wife either thought nothing of him, or he had none. But when I saw a man with the most beautiful embroidery that any woman ever looked at I made up my mind that his wife was a jewel, and was sure that he had one.

Now it is curious, but these things don't offend you at all. Really, I wonder why you don't do this thing yourself. Roumanians are wise people. When they want a thing they want it.

Down in Bucharest I found them jealous of their Polish neighbors, because a gentleman from this sleepy city sometimes called Sleepy Hollow had undertaken to trust the Polander for 150 locomotives, and the Roumanians wondered why the same gentleman who was now in their midst couldn't accommodate them in like manner. Well, of course, they hadn't heard that the War Finance Corporation had blown up and they hadn't heard that money was growing more and more difficult to obtain in this country, but they wanted engines, and it was up to this Philadelphian to devise some means whereby they could get locomotives.

When William Penn came to Philadelphia he treated with the Indians in about the same manner that this same Philadelphian went to Roumania and treated with the Roumanians. The Indians had no use for money, but they did admire the things which William Penn brought over, and they were willing to accept those in barter for things which they could give to him, for land or for skins or other goods, and so in Roumania the first thing which occurred to me was perhaps I might give these people some locomotives for a cargo of glass beads, because I noticed in my office, have noticed for the last year or two, when the girls have nothing else to do they are busy making purses and sewing glass beads all over them, and figuring up the fifty million women in this country and each making one of these bead purses, I felt that we could stand a few shiploads of beads about as well as we could stand anything else. (Laughter.) But as the bead business wasn't good over there, I found the petroleum business was, and after consultations with the ministers and with the King and the Queen, who is a good business woman—in fact, the best business man in Roumania is the

Queen—we arrived at a barter by which we would send them locomotives and they would turn over to us oil.

The question of money was not mentioned excepting that the Finance Minister finally desired the privilege of paying in money or American dollars if he could find any.

Now, my impression there was that these people knew what they wanted and they were willing to accept any reasonable proposition that would place in their hands these locomotives, and now, why locomotives? Because I realized that those peoples in those countries had no use, had no need for our charity, they didn't want it; they didn't want your bacon and eggs; they had plenty of bacon and eggs themselves. They had plenty of wheat in the fields, they could raise all that they could eat and all their friends could eat if they only had something that would carry this food from one place where it was raised to another place where it had to be eaten. If they had locomotives that would carry the oil from the oil fields to the port of Constantinople they could ship it and realize on it. They wanted locomotives to haul lumber from their fine forests to the shores so that England could get it and England was crying for it. To take salt from their salt mines, the finest in the world, so that the price of salt in the civilized nations would fall, and Roumania would prosper from the money which she would get. The locomotive was the key to the situation.

Now that was the chief impression that I got, and the impression I might say impressed me very favorably. So I traveled along and concluded I would go down into Serbia and see what the Serbians looked like. Now I imagined that Serbia was a country that nothing but a goat could travel in, that the mountains were precipitous and the paths narrow and the people were an uncomfortable and not at all genial lot to deal with. In going down to Belgrade I passed through the most beautiful pastoral country that I ever went through. There isn't any land in this country, unless it be Lancaster county, which will this year raise a tobacco crop of over twelve million dollars that could compare with it. I had read in the newspapers for several years of the devastation of this country, of the killing off of all its flocks, of the destruction of its houses, its fields, its roads, and everything else. I never saw such herds of cattle, not even in the Wild West. I never saw such beautiful flocks of sheep. I never saw such beautiful farm hamlets, places for farmers and their families to live in and in one field alone, a good-sized field, I counted twenty-eight ox teams with six pairs of oxen in a team plowing—in a country devastated by five years of war.

Now, probably the troops didn't pass through that particular section, but in Belgrade, which was all shot to pieces, the people were just the same as they were in Bucharest, they were just the same as they were in Poland, they were on the alert, they knew their troubles and they were cheerful over them. And, therefore, it behooved me to find out what they wanted to do. And a tentative arrangement was made to barter for wheat. The impression I gained was that Belgrade or Serbia did not really recognize what her natural products were to her; neither did they in Roumania, and I said, "Why don't you put your finger on these and use them to build up your country, and not allow the speculator to come in and buy this product of yours in your own coin, at a low rate, and ship it out of the country and sell it at an enormous, outrageous profit to those who are anxious to get it," and when I told him the price which I could afford to pay, delivered at Trieste, for wheat, which all I would have to do will be

put it in a vessel and send it around to Belgium, they were astonished, and they said, "If you can pay us that for wheat we will immediately give you an order for all the locomotives you can build." But I told them that I couldn't build very many, that we had to build for everybody and we could only do a little.

Now, coming home, back through Paris you could see the gradual increase of industry in passing through Italy—Italy had barely started to get rid of the remnants of war, the wire and the guards that had been put over the battlefields, the trenches were unfilled, but the reason for that was that the ground was not as fertile or as well inclined to produce as the land in these other countries, especially in France; and the nearer you got to France, the more you realized that the people of Europe could take care of themselves, all they needed was assistance from us in the way of providing them with the machinery and the raw materials with which to commence and for those we would have to find some way of establishing our credit and giving these people time to earn the money with which to repay us for the start which we would give them, and that way is being found, not only by the little company which I represent, but by almost every manufacturer who has been induced to take any interest in the affairs of Europe.

Crossing over the Channel into England one's feelings received a check. I was not at all pleased with the attitude of labor toward capital or capital toward labor that I found in this country. I was not at all pleased with the attitude of the average citizen and working man toward his country. There was a fence up and a very high fence, and a discontented lot of people on either side of the fence, and that is still continuing, and in this recent development where everybody in America who had loaned Poland a dollar was shivering whether Poland would be whipped and wiped off the map in a minute, were trembling in their shoes, England was afraid to put out one single helping hand on account of the Bolshevism which was raging and liable to break loose in that country, and to France alone is the honor of taking a firm stand and long before the Bolshevists approached Warsaw to have started on the way the necessary machinery of war which, under the guidance of a most able French general, was to envelop the Bolshevist army the same as Joffre enveloped the German army outside of Paris in the early years of the war. France, therefore, today, in my judgment, and it is the impression which I formed over there, and which has been further confirmed by the report of one of my people whom I sent specifically to inquire into this matter, is today the dominating state of Europe, and Belgium is her ally, and will be her ally. Together those two states are going to lead Europe out of its trouble and put it safely on its feet. Those, gentlemen, are my impressions from abroad, and, returning home, is it but natural that I should form some new impression of my own country, and what we ought to do? Especially here in Philadelphia, the leading manufacturing city of the United States, we manufacture almost everything here, from ladies' stockings clear down to such a lot of common ordinary things—why, we have been in the manufacturing business over here ever since we started. What other things do we manufacture? I think I have stated it once before to some of my friends in Philadelphia—we manufactured the Declaration of Independence here in Philadelphia, and we manufactured here in Philadelphia the Constitution of the United States, and we further manufactured here in Philadelphia down on Arch street, and the house is still standing, the American Flag,

which every American citizen has learned to love and respect. (Applause.) And the other evening I heard a speaker say something which I will never forget, that in a certain newspaper in New York he saw a flag and this flag was supported and held aloft and there wasn't a star on it, there wasn't a stripe on it, but there was on it "The League of Nations or Nothing." Now, we manufactured the American Flag in this city, and I guarantee you that there are enough true Americans in this great United States, and if they are not in the United States, there is in Pennsylvania enough true Americans to uphold that Flag which we manufactured, to put it up and hold it there, despite any other flag which may be manufactured for the whole United States. (Applause.)

And why, gentlemen and ladies, do I say this? I say this because I have a profound impression of the greatness of Pennsylvania. We always used to hear Pennsylvania called the "Keystone State," but the last war demonstrated the one fact that Pennsylvania was the Keystone State of this country. Pennsylvania furnished one-sixth of all the supplies that went into the American Army. Pennsylvania furnished the majority of all the steel that was employed. Pennsylvania furnished all the heavy artillery or practically all—the only heavy artillery that went into France and into action came from the banks of the Delaware. Seventy per cent of all the military rifles that our soldiers carried were manufactured here in the East out of Pennsylvania steel, with Pennsylvania workmen, and at Chateau Thierry Pennsylvania men with Pennsylvania rifles turned the troops of Germany back.

Now, this is a little bit only, because last year when the Government after a wild orgy in the way of expenditures and the greatest taxation that this country has ever suffered from, Pennsylvania paid more than one-sixth of the national tax, and that after having furnished more than one-sixth of the soldiers which went into the American Army. And what now will Pennsylvania do? Pennsylvania is going to furnish one-sixth or more of all the necessities of a war, a war among ourselves, to restore the United States to what it was before the war, before we had such things to endure as we have had during the war and since the war. Gentlemen, the effort of Pennsylvania—and it will be no mean effort—will be to put Pennsylvania and the whole of the great United States once more back on the pike and not on a detour. (Prolonged applause.)

NOTICE

CHANGE OF HEADQUARTERS

Beginning November 20th, 1920, address all correspondence to

AMERICAN SOCIETY FOR STEEL TREATING

4600 Prospect Avenue
CLEVELAND, OHIO

FUELS AND THEIR APPLICATION TO METAL TREATING

By W. A. Ehlers.*

(A paper presented at the Philadelphia Convention.)

The science of metal treating is unquestionably one of the most interesting and important subjects in the mechanical field today, and one which calls for the most careful and comprehensive study and application, if correct results are to be secured.

Metal treating has come into greater prominence in recent years, due in a large measure to the ever increasing demand for lighter, yet stronger and more durable moving parts in all forms of machinery subjected to unusual wear or shock, and also on account of the great development in automatic and special machinery.

Unfortunately many shops are still treating tool steel in the old blacksmith forge, which is as much a relic of the "dark ages" as the ox cart is in the field of rapid transit. Steel cannot be successfully treated in the coal forge, due principally to the condition of uneven heating. Uneven heating produces uneven cooling, which in turn produces uneven stresses in the piece when it is quenched and hence will shorten the life of the finished part.

A uniform temperature throughout the entire heated area is necessary, if correct results are to be obtained. It is surprising to find that many practical steel treaters continue to use the old and crude method in treating expensive steel, because they do not see the wisdom of purchasing modern furnace equipment, which will give better results and greater economy, by prolonging the usefulness of the tool.

It is of interest to note that many of the manufacturers of so-called "special steels" for tool making purposes, recommend that they be heat treated in gas fired furnaces.

Certain fundamental conditions enter into the processes of metal treating which are of great importance. One of these is the necessity for obtaining uniform results, and the elimination of the possibility of producing work below the required standard. To obtain uniform results it is very necessary to regulate, and maintain the temperature of the furnace within a reasonable degree of that required for the particular operation. This imposes the condition that the fuel must be of such nature that the amount of heat delivered can be changed very quickly. It is also necessary to have positive control of the furnace atmosphere.

The ideal furnace is one which maintains an evenly distributed heat throughout the parts to be heated, when loaded to its capacity, and one in which the temperature and combustion products are under positive control.

From chemistry we learn that matter may be defined as that which ocupies space; that matter is composed of infinitely small particles known as molecules. Molecules are again composed of atoms, and these combine to form elements or compounds. Thus like atoms will form an element, and when combined with atoms of other substances they form a compound.

It has also been proven by experience, that the molecules of all matter are never at rest, but are always in motion and the motion of these molecules produces heat, therefore the greater the activity of the molecules, the greater will be the amount of heat produced, all other things remaining unchanged.

Moreover each combustible substance has a definite temperature of

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ignition and when certain of these molecules reach the temperature of ignition they have a great affinity for oxygen. The resulting chemical union between these atoms gives rise to what we term combustion. Combustion has therefore been defined as "the phenomena produces on the surface when two substances unite to give light and heat."

In a further study of combustion there are certain fundamental factors and conditions to be met if proper combustion is to be obtained and the resulting heat properly applied. All fuels are made up of combustible substances, each giving a certain definite temperature of ignition and each forming a new compound when mixed with the proper amount of oxygen at the point of ignition. This leads to the conclusion that perfect or complete combustion can take place only when these substances are mixed with oxygen in the proper proportion. Or, stated in more familiar terms, a definite amount of air is required to completely burn a given quantity of fuel.

The properly designed furnace is an important factor in heat treating. Time will not permit me to go into this very important subject. Poorly designed furnaces are not only uneconomical but they are largely responsible for unsatisfactory results. Many furnaces are operated without knowledge of the composition of the furnace atmosphere; with no control of the air supply or flue gases. There are certain fundamental principles such as type of construction, kind of fuel and the means of utilizing the heat of combustion that govern the design, but in general the character of the work to be performed, the kind and quantity of materials to be treated are the controlling factors. The real test of a furnace for a given operation is "the variation in temperature in all parts of the furnace around the mass to be heated when the chamber is loaded to full capacity."

One of the things first to be considered in the proper heat treatment of metals is the kind of fuel necessary to produce the character of heat best suited for the particular operation. Unfortunately there is a prevailing belief among many that when it is desired to heat treat a piece of steel the only thing necessary is to build a fire and plunge the material into it. If results are not forthcoming they blame the steel perhaps and not the method, which, in most instances, is the real cause.

For all practical purposes fuels may be clasified into solid, liquid and gaseous. It must be remembered that in the case of solid and liquid fuels, each must first be converted into gas before combustion really takes place, and for this reason they are not so easily adapted to exact furnace conditions and temperature control.

Of the solid fuels, coal and coke are principally used. Lump coal and coke are not very well suited for metal treating operations, except in very large furnaces for pack annealing and case hardening in large quantities. Even with these it is not easy to maintain a uniform temperature, and there is great danger of overheating. At best they are very wasteful of fuel, and it is difficult to control the products of combustion which is particularly essential where the metal is subjected to the direct action of the flame.

Powdered coal has a great advantage over lump coal or coke in that it may be termed a "one stage" combustion being complete and free from residual carbon. It burns directly to CO_2 without the attending losses of unburned carbon and carbon contained in the ash. Its chief disadvantage, however, lies in the mechanical preparation of it, as it must be crushed, thoroughly dried and stored, also in the harmful action of the ash upon furnace walls and linings.

Liquid fuels generally exist in the form of kerosene, gasoline, and fuel

oil. Owing to the great demand for kerosene and gasolene for internal combustion engine and other purposes, their cost has advanced to such a point that they cannot be considered for the heating of furnaces. Fuel oil as a general rule is more expensive to use than coal or coke, but its superiority over these fuels in its form of application to the furnace is sufficient to overcome the increased cost. Fuel oil is a by-product of crude oil refining, and its cheapness in the past has been due principally to crude methods in refining and an over production of crude oil. With the increasing demand for motor fuel, improvements have been made in refining methods, which have very materially reduced the fuel oil available for metallurgical purposes. This situation is largely responsible for the scarcity of fuel oil and the unprecedented high price, and according to reliable authority, including the U. S. Bureau of Mines, very litttle hope is given that it will be any cheaper for sometime to come.

A good grade of fuel oil will range from 18,500 to 20,500 B. t. u.'s per pound, and a vaporizing point of about 170° F. Considering that air is composed of 20.7 parts oxygen and 79.3 parts nitrogen, one pound at 62° F. occupies a space of 13.141 cubic feet, and at 100° F. one pound occupies 14.096 cubic feet. Theoretically it requires about 14 pounds of air to give perfect combustion of one pound of oil. Therefore it will require 14×14.096 or 197.34 cubic feet of air to burn one pound of oil at 100° F. However, in practice it requires from 17 to 20 pounds of air or in round figures 2000 cubic feet of air at 100° F. to completely burn one gallon of fuel oil.

In admitting oil to the combustion chamber of the furnace it must be broken up into a fine spray, commonly spoken of as atomized, by means of a suitable burner. Atomization may be obtained in one of three ways:—Live steam, compressed air, and mechanical process. Of these compressed air is more generally used.

Where air is used for atomization it is usually found to vary in pressure from 1½ pounds to 60 pounds per square inch, depending upon the kind of burner used. The majority of installations work with an air pressure of about 20 pounds per square inch. This, however, is higher than necessary for good results. With air under a pressure of 20 pounds per square inch and oil at 100° F. there is required about 50 cubic feet of air per pound of oil.

Steam for atomizing is not so generally used in industrial operations, due perhaps to its greater cost over compressed air. Moreover in many places it is not available. According to Durand, 0.4 pounds of steam are required per pound of oil. This agrees closely with some investigations reported to the American Society of Mechanical Engineers (Aug. 1911 Bulletin) which give an average of 0.5 pounds per pound of oil. The latter is perhaps a safer figure to use.

Fuel oil often contains a small percentage of water which lowers its heating value. For each one per cent. of water the heating value is reduced 13.14 B. t. u.'s. Thus for an oil having nominally a heating value of 18,500 B. t. u.'s per pound and containing 10 per cent water the heating value is reduced to 16,518.6 B. t. u.'s or a loss of 1982 B. t. u.'s. If water is in the oil, combustion is incomplete, the violet flame never appears, but the end of the flame will be dark red and fringed with smoke.

Fuel oil being rich in hydrocarbons, gives a very high heat for a comparatively small volume of oil. For this reason it is particularly adaptable to heavy forging work, such as drop forging; the heating of

heavy bars and rods for forging and upsetting. It is also a very excellent fuel for welding.

But there are many things which must be considered before selecting oil as a fuel, particularly on the purely heat treating operations. There is the necessity for a large and expensive storage tank which must be buried in the ground. This tank frequently leaks and much oil is wasted before the leak is discovered. Smoke, grease and the roar of burners under high pressure are serious objections, and these are not conducive to making the surroundings pleasant for the shop men.

Moreover the use of oil does not permit of automatic temperature control by placing a thermovalve in the fuel line. Conditions affecting a continuous supply are not the best and frequently much time is lost waiting for a new supply.

Gases which are most generally used for fuel purposes are natural gas and the manufactured gases such as coal gas, coke oven gas, water gas and producer gas. These gases are pre-eminently suitable for and by far the most satisfactory fuel for metal treating processes. These facts combined with the economic advantage makes gas the coming fuel of the future.

Gaseous fuel is economical, because it can be applied in a way most adaptable to the requirements of the material to be heat treated. Other fuels as a rule must be burned in the furnace in a certain fixed way, there is very little flexibility in their application. Gas on the other hand can be applied in a way that will give the best result with the least waste of fuel.

By its nature and composition gas offers the greatest advantage from a purely scientific point of view. It is easy to thoroughly mix it with the proper amount of air for complete combustion. With other fuels this is impossible. Control of the air-gas ratio means a higher rate of combustion, a relatively higher flame temperature, and therefore a higher thermal efficiency.

The cheapest fuel, even with other things being equal, is not necessarily the one which gives the greatest number of B. t. u.'s per unit of cost, but the one which costs less per unit of production. Numerous examples can be given to prove this statement. However, one or two should be sufficient. In a certain town in the state of New York gas selling at a rate of approximately one dollar per thousand cubic feet replaced soft coal at about five dollars per ton for bright annealing copper wire. It was first demonstrated in an experimental way that coal was the most expensive fuel for this particular operation, although it contained perhaps four times more B. t. u.'s per unit of cost than found in the gas. It further demonstrated the fact that the thermal efficiency of the gas furnace was several times greater than the coal furnace.

A large oil producing and refining company used large quantities of manufactured gas for heating solder baths at their refinery, where there was almost an unlimited quantity of crude oil, fuel oil, gasolene and kerosene.

The industrial heating department of a large and well known gas company found from actual operations that under the best conditions of oil utilization they could substitute 1000 cubic feet of a 600 B. t. u. manufactured gas for 5½ gallons of 142,000 B. t. u. oil. Where oil was used at a low efficiency this company found that 1000 cubic feet of 600 B. t. u. manufactured gas could be substituted for 14 gallons of oil of 142,000 B. t. u.'s per gallon.

In other situations the same company was able to substitute 126 B. t. u.'s of manufactured coal gas for 210 B. t. u.'s of producer gas. Again, 253 B. t. u.'s of manufactured coal gas gave the same results as 504 B. t. u.'s of producer gas.

The above occurrence confirm the statement that fuels cannot be compared in relative heating value by their B. t. u. content in the fuel state. The only correct basis of comparison is the heating value of the combustible mixture. This fact is well established theoretically. A few calculations will show that a coke oven gas of 600 B. t. u.'s per cubic feet will give a theoretical flame temperature of 3550° F. and a heat content of 100 B. t. u.'s per cubic feet in the products of combustion. While a blue water gas of 300 B. t. u.'s per cubic feet will develop a flame temperature of approximately 4000° F. and a heat content of 107.5 B. t. u.'s per cubic feet in the products of combustion.

Yet in the face of these facts, both theoretical and practical, we find many practical steel treaters in favor of coal and oil because of their erroneous belief that the B. t. u. value of the fuel as fired to be the real measure of its utility.

The principal combustibles in the fuels under consideration are carbon, hydrogen, and their many combinations known as hydrocarbons, also carbon monoxide. In addition to these are the incombustible such as nitrogen, oxygen, sulphur, carbon dioxide and ash. The combustible elements when mixed with air give a flue gas composed of carbon dioxide, water vapor, sulphur dioxide, nitrogen and carbon monoxide. Furthermore by changing the proportion of air in the flue gases gives rise to three general conditions within the furnace:—a reducing, neutral, or oxidizing atmosphere. These conditions are essential and are of great importance in different heat treating processes. They also have a very vital relation to fuel economy and furnace efficiency.

A reducing atmosphere (one in which an insufficient amount of oxygen has been admitted with the fuel to give complete combustion), is a condition often desirable in heating tool steel and other steel parts, in order that no oxidization or scaling action shall take place. The flue gases should show a small percentage of unburned gases.

A neutral atmosphere is one which is hard to obtain with any of the fuels except gas. It represents a condition in which just enough oxygen has been admitted to completely burn the carbon hydrogen, and other combustibles present. In this case a flue gas analysis will show no free oxygen or unburned gases.

The condition most frequenttly found in furnaces is the oxidizing atmosphere, where an excess of oxygen is necessary to accomplish certain results, or where too much has been admitted through poorly designed apparatus. This condition is very noticeable in coal fired furnaces, where it is necessary to burn the coal with a large amount of excess air. Such a condition within the furnace is harmful in many ways. It causes over ventilation and thus carries away much of the sensible heat of the unburned gases. It produces a chilling of the flame, lowers the temperature of the furnace, and thus reduces its thermal efficiency. Steel exposed to this furnace condition oxidizes very rapidly.

For industrial heating operations, gaseous fuel should always be mixed with air before the gas has reached the zone of combustion, and in the proper proportion to give the desired furnace atmosphere. For all metal treating work, some mechanical means should be used to produce air at sufficient pressure, and thoroughly mix it with the gas. This

is of great importance in burning gas. Many devices are used, but all may be grouped under three general types.

(1.) The Air Injector—air under a pressure of a few ounces to one or two pounds per square inch is passed through an injector. Gas is admitted to a chamber surrounding the injector and the high velocity of the air in passing through the injector opening entrains the gas and the mixture is then led to the burner. This method requires both air and gas piping to the injector. It further requires valves on both the air and gas pipes and these are changed by the furnace attendant to give the desired mixture.

(2.) Gas under relatively high presure—under a pressure of from 8 to 10 pounds per square inch gas passes through a small orifice, and entrains air under atmospheric pressure. The resulting mixture is led to the burner located nearby.

(3.) Gas and Air Mixing Machines—a machine designed for this special purpose is located at a convenient point. Air and gas are brought together inside the machine in any predetermined proportion within the limits required for combustion. By means of a pump or fan the mixture is distributed from this point by means of a one pipe system to the point of consumption.

It is to be regretted that in the majority of gas fired furnaces the air injector is used for mixing. This is largely due to a lack of initiative in the past on the part of gas engineers, and also on account of the ease with which an injector may be constructed. We have no particular antagonism to the air injector as a mechanical means of mixing the air and gas, but the greatest evil lies in the very uncertain proportions of air and gas thus obtained by means of manual adjustment of the valves usually administered by unskilled furnace attendants. It is no exaggeration to say that the ordinary furnace fitted with an air injector and a two pipe system, and operated by the average furnace attendant will use as much as 50 per cent. excess air.

With the high pressure gas inspirators and air-gas mixing machines it is very easy to make adjustments that will mechanically control the air-gas ratio to give the desired furnace condition. After this adjustment has been made it is only necessary for the furnace attendant to regulate one valve in order to give more or less heat as the occasion may require.

The application of heat in furnaces to the metal to be treated is another subject of great importance and one too often overlooked. Heat may be transferred from one body to another, or applied to a body from the point of combustion in three different ways:—by conduction, convection and radiation.

Heat transfer by conduction takes place when it is transmitted from one part of a body to another without the occurrence of motion in any definite part or parts of the body intermediate points being heated meanwhile. Thus a steam radiator becomes hot on the outside due to **conduction** of the heat of the enclosed steam within the radiator which passes through the iron to the exterior. Placing one's bare foot on a tile floor in a room well heated will give the impression that the title is very cold. While if the foot is placed on a rug it will feel much warmer. As a matter of fact the tile and rug are perhaps of the same temperature, but the tile being a much better conductor than the rug, absorbs the bodily heat from the foot much quicker than the rug and is therefore known as a good conductor.

Heat transfer by convection takes place when it is conveyed from one place to another by the movement of air currents, or the circulation of liquids. When heat is applied to the bottom of a pan of water, almost instantly minute vapor bubbles form in the bottom of the vessel. These presently ascend and impart heat to other parts of the water, while cooler water takes its place at the bottom.

Heat transfer by radiation takes place when heat is transferred from a hot body to a colder one by a wave like motion of the ether that occupies all space. The ordinary cast iron steam or hot water radiator warms the room by reason of the fact that the heat of the radiator starts a wave like motion of the surrounding ether in all directions, and as these travel outward from the radiator, similar to the waves of water when a stone is thrown into a still pond, the heat is imparted to the room, and this transfer of heat is called radiation.

For all practical purposes of furnace design, the heat of combustion is transferred to the material to be heated by means of convection and radiation. Heat transfer by conduction is to be avoided as much as possible for by this means the efficiency of the furnace is very much lowered if heat is allowed to be conducted through the furnace walls and lost. For this reason it is important that all furnaces should be thoroughly insulated with the best kind of nonconducting material, in order to reduce such losses to a minimum.

In the usual type of furnace, the heat is transferred by convection to the walls and arched roof, and from these a radiant heat transferred to the material to be heated. Then in order to get the maximum amount of radiant heat from the gas burned, there must be as near complete combustion as possible with a minimum amount of flue products.

The proper furnace conditions are hard to obtain with any degree of certainty or uniformity when coal, coke or oil are used to produce the heat. On the other hand, gas on account of its flexibility of application, can be made to accomplish far better results.

Coal and coke are seldom considered today in connection with the larger and more important heat treating operations, because of the difficulty in maintaining proper furnace conditions.

Oil can no longer be considered a cheap fuel for furnace heating on account of the economic demand for it for other purposes.

Natural gas supply is continually growing less, as evidenced by the increase in shortage during the winter, and the construction of manufacturing gas plants to augment the supply.

Producer gas plants and others that use coal at the sacrifice of the valuable by-products will sooner or later go into the discard.

It is possible we are approaching the dawn of a new day in industrial economy. A day when the gas manufacturing company will become a central fuel station from which can be supplied the entire fuel demand for industrial heating. But on account of the ridiculously unreasonable standards of candle power and heating value placed upon the gas companies by the State Utility Commissions in the past it has not been possible to produce a gaseous fuel of the greatest economic advantage.

The question of fuel costs is a very vital one to every manufacturer. Unfortunately a decision has often been reached on a purely heat unit basis, without considering the efficiency of application, and many items of expense incurred in handling such fuels before they reach the zone of combustion.

In the foregoing remarks the aim has been to state a few of the char-

acteristics of each fuel together with some of their advantages and disadvantages. It must be remembered that the true fuel cost is not the cost of coal per ton, oil per gallon or gas per thousand cubic feet delivered at the factory, but rather the cost of these fuels delivered to the hearth or burner of the furnaces.

There are many items of expense such as the handling of coal, removal of ashes, investment in storage equipment, labor, time lost in getting started with coal or oil, the noise and smoke nuisance so peculiar to the oil fire, and the deteriorating effect of coal and oil on the furnace causing frequent repairs. The proper fuel is the one which regardless of cost per ton, gallon or cubic foot, gives the correct heat application, perfect combustion, and proper temperature control.

Therefore in the final analysis the true furnace efficiency is measured by the quality of the work it produces and the cost per unit of product, and not upon the relative cost per unit of fuel consumed.

MICROCONSTITUENTS IN ONE SECTION OF A METCALF TEST BAR

By Oscar E. Harder, Ph.D.*

The test which has come to be known as the "Metcalf Test," was originally outlined as follows:[1] "To show this effect we take a bar of steel of ordinary size, say about inch by half, heat six or eight inches of one end to a low red heat, and nick the heated part all around the bar, at intervals of half to three-quarters of an inch, until eight or nine notches are cut. This nicking is done at a red heat to determine the fracture of the nicks. Then place the end of the bar in a very hot fire, leaving the balance of the bar so much out of the fire as to heat it chiefly by conduction. Heat the end of the bar in the fire to white hot, or until it scintillates, and allow it to remain until the nick furthest from the end in the fire is not quite red, and the next barely red. Now, if the pieces be numbered from one to eight, beginning at the outer (hot) end,

No. 1 will be white or scintillating;
No. 2 will be white;
No. 3 will be high yellow;
No. 4 will be yellow or orange;
No. 5 will be high red;
No. 6 will be red;
No. 7 will be low red;
No. 8 will be black.

As soon as heated as above described, let the bar be quenched in cold water, and kept in the water until quite cold."

The information which Mr. Metcalf considered could be obtained from this test is indicated in the following quotation: "First: (a) A difference in temperature sufficiently great to be seen by the color will cause a corresponding difference in the grain. (b) This variation in grain will produce internal strains and cracks.

"Second: A temperature so high as to open the grain, so that the hardened piece will be coarser than the original bar, will cause the hardened piece to be brittle, liable to crack and to crumble on the edges in use.

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*Associate Professor of Metallography, University of Minnesota.

1. Metallurgical Review, vol. 1, pp. 245-253 (1877-8).

"Third: A temperature high enough to cause a piece to harden through, but not high enough to open the grain, will cause the piece to refine, to become stronger than the utempered bar and to carry a tough, keen cutting edge.

"Fourth: A temperature which will harden and refine the corners and edges of a bar, but which will not harden the bar through, is the proper heat at which to harden taps, rose bitts and complicated cutters of any shape, as it will harden the teeth sufficiently without risk of cracking and leave the body of the tool soft and tough, so that it can yield a little to pressure and prevent the teeth tearing out."

Since the original test was described it has been used extensively for demonstration purposes in educational institutions and shows to the students, in a very striking way, the effect of temperature on the grain size and hardness of steel.

This test has an additional use in that it may enable the practical shop man to determine experimentally the temperature, as judged by the eye, required to give the best refinement of the grain in a particular steel and, therefore, enable him to judge with a reasonable degree of accuracy the proper temperature for heat treating that steel.

So far as is known to the writer, the microconstituents of what may be termed the "critical section" (i.e. the section which has been heated to just above the upper critical point) of the Metcalf test bar have not been published, and it is that feature of the test which is to be considered in the following notes.

The steel used in this test contained 1.17% carbon and was ¾-inch round open hearth steel. The test was made about as recommended in the directions quoted above and the microconstituents of this particular section carefully studied.

Figure No. 1 shows the fracture, at a magnification of four, of the end of this section which had been heated to the higher temperature. It is evidently over-heated and the grain coarsened as a result. Fig. 2 shows the microconstituent found at this end of the bar and is evidently martensite. This, of course, is exceedingly hard and brittle. The relative positions of the photomicrographs represented by Figures 3 to 10 are

Fig. 1. Fracture × 4

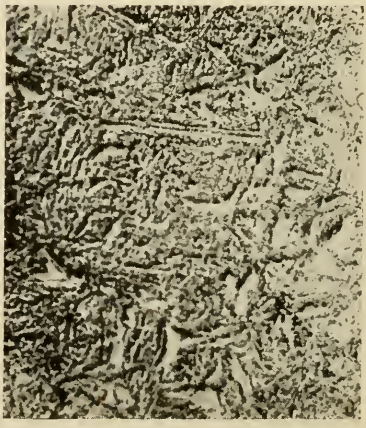

Fig. 2. Martensite × 800

shown in the following table in which the distances from the over-heated end of the bar are measured in millimeters.

Figures	Distance in mm.
3	6
4	9
5	11
6	18
7	21
8	26
9	24
10	27

Fig. 3 shows the beginning of the appearance of troostite—the dark areas. In Fig. 4 troostite predominates and the martensite (light portions) occupies probably not over 25% of the area. In Fig. 5 the martensite has completely disappeared and the whole mass appears to be troostite. Fig. 6

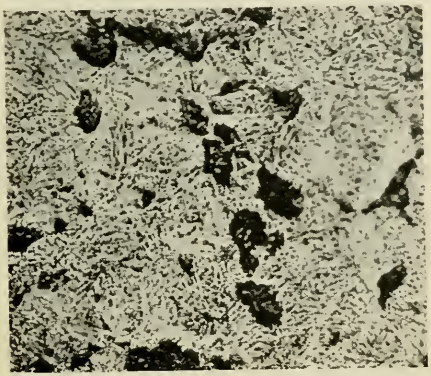

Fig. 3. M. + Troostite × 800

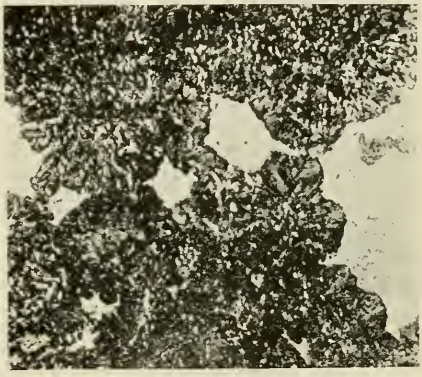

Fig. 4 + M. × 800

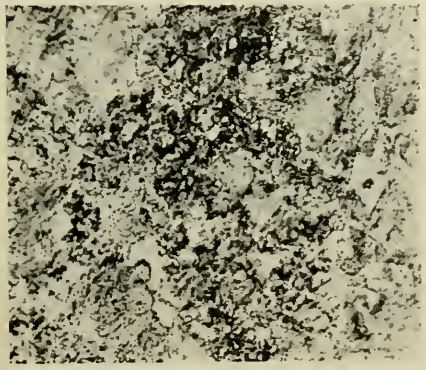

Fig. 5. Troostite × 800

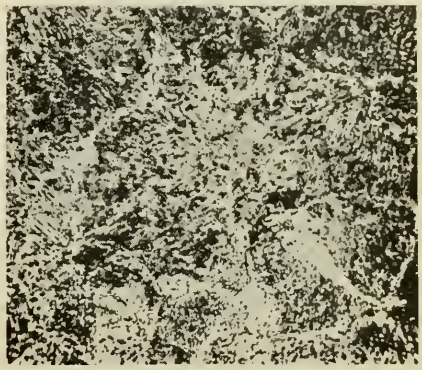

Fig. 6. T. + Cementite × 800

shows troostite and excess cementite, as would be expected in a hypereutectoid steel containing 1.17% carbon. Fig. 7 has been termed osmondite because of the readiness with which it was attacked by acid. Some authors do not recognize this constituent and there may be some question about

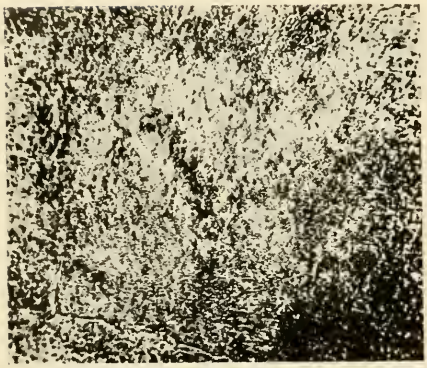

Fig. 7. Osmondite × 800

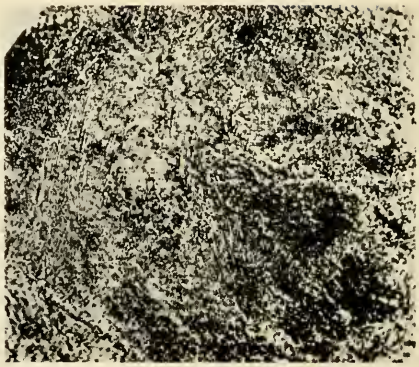

Fig. 8. Sorbite × 800

Fig. 9. S. + Pearlite × 800

Fig. 10. Pearlite × 800

Fig. 11. Fracture × 4

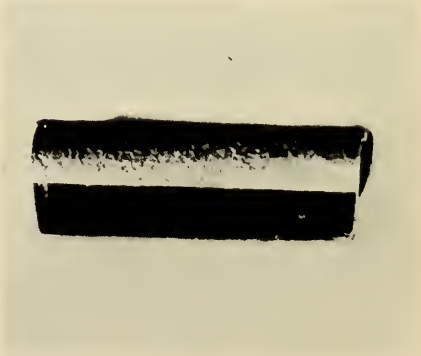

Fig. 12. — Test Bar × 1

the advisability of trying to distinguish it from troostite and sorbite. Fig. 8 is a fair representation of sorbite and, doubtless, corresponds approximately to section No. 7 as referred to in Metcalf's original communication. Fig. 9 shows the first appearance of pearlite and Fig. 10 shows a field composed of pearlite with some excess cementite. Fig. 11 shows the fine

grained fracture at a magnification of four, and Fig. 12 shows the original test bar at actual size.

It probably has not occurred to most people that a small section of rod, 1¾ inches in length, when treated as is the custom in making the Metcalf test, would contain all of these microconstituents, and it is for the purpose of demonstrating that fact that this brief paper has been prepared. Most of the work was done by Mr. H. S. West, a junior metallurgical engineer in the School of Mines.

DISCUSSION OF DR. HARDER'S PAPER

CHAIRMAN: We have all listened with a great deal of interest to this presentation by Professor Harder showing the various microconstituents of the sections taken from a Metcalf Test Bar. Is there any discussion on this paper?

MR. STAGG: I was talking to a gentleman this morning and he said, "Stagg, why is it that I can cut a die from a bar, cut another die from that same bar of tool steel, and a third die from the same bar of tool steel, and give them the same treatment, and why is it that from one bar I can get a production of 100 parts, from another one 1,000, and from the third 15,000? I think those microphotographs will certainly tell that gentleman something about "Why."

CHAIRMAN: Professor Harder has traveled a good many miles to get here; I think it runs way over the thousand mark; I know he would appreciate some discussion of his paper this morning.

MEMBER: I would merely call the attention of the members here to the fact that precisely the same range of metallographic constituents can be had in as short or even a shorter space in an ordinary butt-welded piece of high carbon steel, and yet the butt-welding is done in an electric butt-welder. In welding, for instance, a piece of high carbon on a low carbon shank or making a drill bit, even though not more than a quarter of an inch at the joint is polished before any annealing is done, the beautiful range of metallographic constituents can be seen, ranging from austenitic in some cases down to the un-annealed material existing in the original bar, and in nearly every case you will find the line of demarcation from one constituent to another very well marked indeed. It is a fine example of structure for that.

MR. STAGG: A thing which I use for making the Metcalf test quite frequently is instead of taking a bar and niching it at certain points, certain prescribed distances, and fracturing and polishing, etc., is to take a short bar, notch the bar the entire length, heat it up as for a Metcalf Test to the various temperatures and then drive a wedge in and split the whole thing open. That gives me a perfect picture of the whole thing at once, and if I desire to make a micro-section all I have to do is to polish the other side of that and I have the whole story in one.

PROFESSOR KELLER: Professor, I want to state for the benefit of Mr. Stagg that that was one of the procedures followed in the University of Purdue to explain to the students the various changes that took place in an annealed state to a high temperature, and by splitting the bar you bring out very distinctly at just what position the critical range takes place.

Another noticeable fact is that if you will observe the bar closely you will see that the changes of the curve occur, naturally, on the outside first,

until it reaches or penetrates the entire bar. A very desirable length and thickness for that form of test is about four inches long, a quarter inch thick. And let me suggest that you only mark one side, and be sure that it is perfectly straight when you attempted to break it. Keep it perfectly straight before you attempt to break it. I would advise those who are attempting to use that method as a test to try that out. You will learn much about the fracture of a piece of steel.

MR. ELLINGER: For the benefit of those who will not be able to carry out such a test, either for lack of time or facilities, I want to refer you to the Proceedings of the Society for Testing Materials. I think it is the 1918 Proceedings, wherein this was very thoroughly discussed and illustrated with photomicrographs.

TIME, TEMPERATURE AND HEATING MEDIA FUNCTIONS IN HARDENING TRACTOR WORMS

By J. L. McCloud*

The rather interesting fact that it requires less time to heat a piece of Steel of any given furnace temperature is shorter, the higher the temperature, was brought out by F. C. Wagner, *Proc. Am. Soc. M. E., Vol. XXVI. Some work done by the writer in connection with prescribing heat treatment for tractor parts emphasized this fact along with some important relationships between various heating media.

This work was started in a study of the heat-treatment of tractor worms. After having experimented for considerable time with the carburizing of gear in general, we became convinced that we could get better machining qualities, enormously higher physical properties; easier heat treatment and grinding at much lower cost by using oil hardening gear stock.

At this time, let me point out that at the offset we reduced the annealing time of a .42%, .52% Carbon, 1% Chromium Steel from the customary 12 to 20 hours time to 2½ hours. The proper annealing or normalizing of a steel of this class is accomplished in three stages. The steel is first brought to a temperature of 100-150 deg. F. above its critical point on heating (which is about 1,450 deg. F.).

It is then allowed to remain at this point long enough to relieve all forging strains and for all of the carbides to go into solution. From this temperature it is allowed to cool at a definite rate to just below its critical point on cooling. At this time we found a convenient way to handle the stock was to quench it in boiling water. This enables the stock to be handled easier and in no way affects its hardness or machining ability.

The question of machinability in this material we found to be a function of the Brinell hardness, a point we watch with care and hold between the rather narrow limits of 179 to 207. All this annealing treatment we do in a push or continuous type of furnace. The furnaces themselves are described in detail by Heiser and McCloud in the June 1920 number of the American Drop Forger.

The value of a furnace of this type can be readily understood by an inspection of the figure 1, which shows the heating and cooling curves of loads of 200 and 120 tractor worm forgings (31″ each and 3½″ in diameter in the center). In reality the continuous furnace accomplishes this work in

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*Chemist, Ford Motor Co., Tractor Division, Dearborn, Mich.

so short a time as 2½ hours, due to the fact that the quantity of stock in any zone of the furnace is low and the sensible heat of the furnace body itself is utilized better, since the temperature of the furnace at any given point remains constant, as long as the furnace is in operation.

The continuous furnace has a capacity of 1900 lbs. per hour, and occupies a space two to three times that of the furnaces just mentioned, but yields about six times the work.

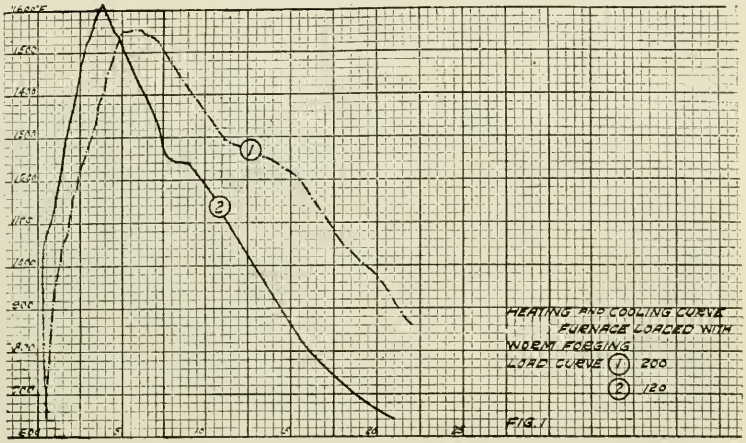


Figure No. 1

Another point of interest in figure 1, is the position of the thermocouple lag, about 1,250 deg., in both cases on cooling. This is about the same as the Ar point as determined on a single small piece of steel in the laboratory (see Griffiths Am. Soc. T. M. Vol. XVII, part II, page 33 and Fig. 8.).

In our study of the tractor worms, we found that with a piece of this large size, the ductility of a piece which was hardened all the way through

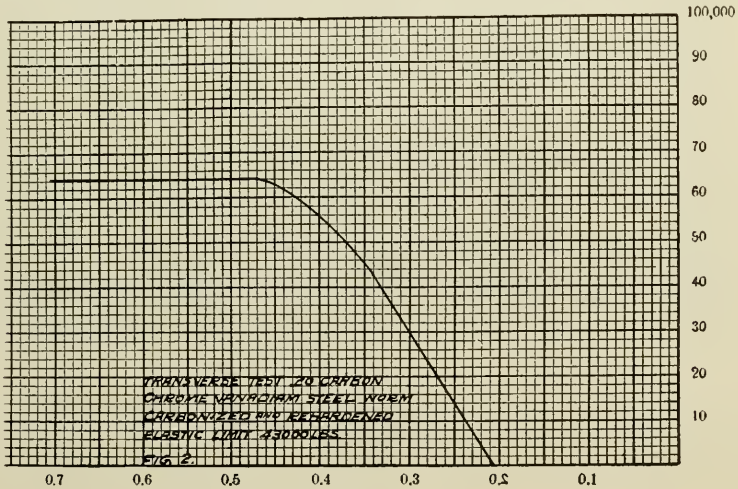


Figure No. 2

was not as high as might be desired. The figure 2 shows the stress strain diagram of a .20 Carbon Chromium Vanadium case-hardened all the way through and figure 3 a .50 Carbon Chromium Oil hardened worm hardened all the way through. To be sure the elastic limit of the oil-hardened piece is nearly double that of the case-hardened worm, but its deformation beyond the elastic limit is nil.

Being desirous of obtaining all the benefits of the oil-hardening stock cited before and at the same time to obtain the ductility of the softer stock we set out to improve the harder worm.

You will note from the figure 5 that the heating time for a single finished worm in air at 1540 deg. F. is forty minutes. The time to heat a

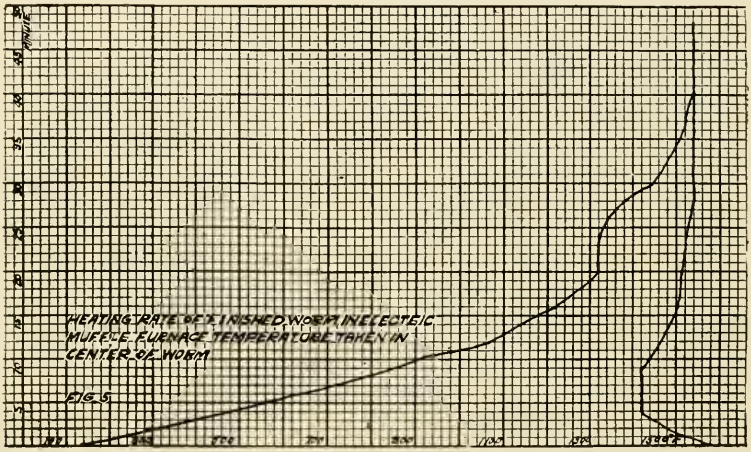


Figure No. 5

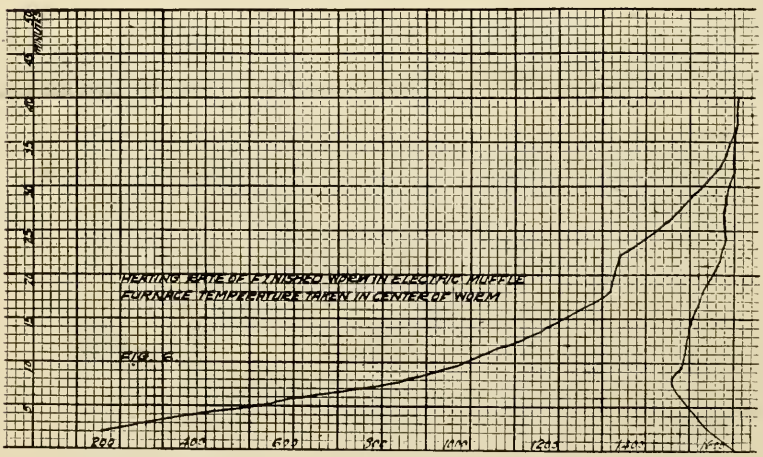


Figure No. 6

finished worm, figure 6 in air at 1600 deg. F., is 36 minutes. These curves were taken in an electric muffle furnace.

The right hand curves show the furnace temperature taken by means of a Le Chatelier Platinum, Platinum-Rhodium Thermo-couple and an

Englehard Millivolt Meter. The lower lines show the temperature of the center of the work taken by means of a similar couple and a Leeds and Northrup Potentiometer. Both curves were corrected to the same cold junction temperature of 32 deg. F. and the couples were previously checked against each other with a delicate meter graduated in tenths of microvolts.

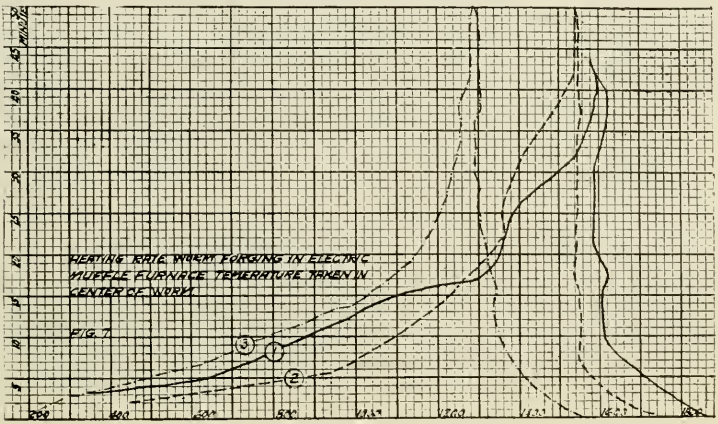


Figure No. 7

At this time let me point out that according to curves in figure 7 the statement by Wagner, cited before, requires some modification in certain cases. These curves were taken in the same manner just described, but were taken on solid worm forgings before the generation of the teeth. The solid lines show the heating time for the center of the forgings with a furnace temperature of 1600 deg. F., the dash lines the heating time for the furnace temperature of 1540 deg. F., and the dotted lines the heating time for the furnace temperature of 1300 deg. F.

You will note that the heating time to bring the forgings to a temperature just below that of any of the three say 1200 is in accordance with the statement of Wagner, namely the time to heat the forging in a furnace of 1600 deg. F. is less than that to heat to the same temperature using a furnace temperature of 1550 deg. F. and the time to heat to the same temperature using a furnace temperature of 1300 deg. F. is greater than that using a furnace temperature of 1550 deg. F.

Likewise the time required to bring the forgings to the furnace temperature of 1600 deg. F. is less than that required to bring the forgings to the furnace temperature of 1550 deg. F. But the time required to bring the forgings to the furnace temperature of 1300 deg. F. was just the same as that to bring it to a furnace temperature of 1550 deg. F.

This might be explained by the temperature lag of the forgings in the case of the 1600 and 1550 deg. F. runs due to the absorption of heat at the critical point, in which case the Ac point is clearly defined as 1350 deg. F., and which incidentally is about 100 deg. lower than that determined on a small piece by the differential method and shown in figure 8.

Figure 9 shows several points of interest and is the one that proved of greatest value to us in devising our heat treatment of oil hardening worms.

These curves were taken in a molten salt bath of the composition 50%

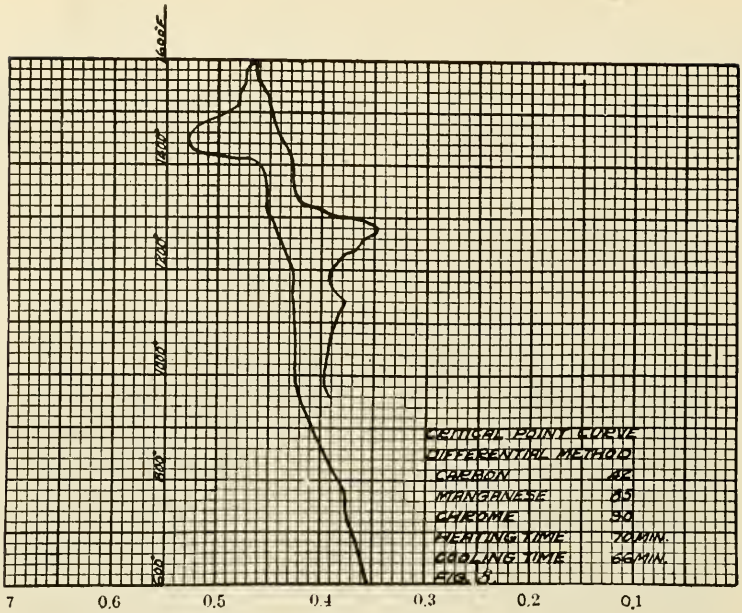


Figure No. 8

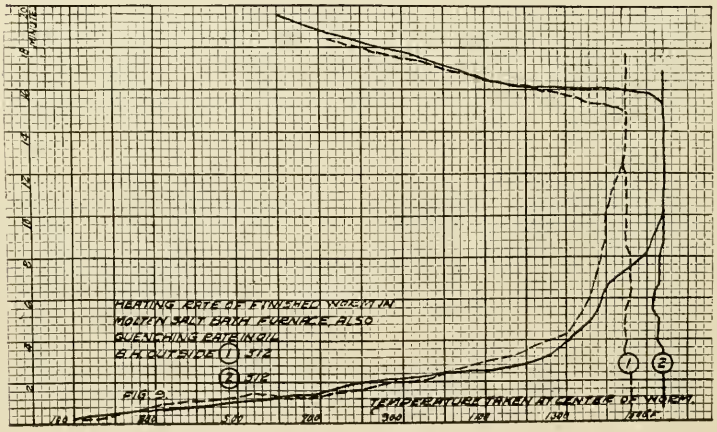


Figure No. 9

Sodium Carbonate, 37½% Sodium Cyanide and 12½% of Sodium Chloride, which makes a convenient, cheap and clean bath for hardening gears. The effect of the cyanide in this proportion on parts of this size, and for the times shown is negligible as far as any case hardening is concerned. You will note the greater rate of heating to 1540 deg. as compared to 1470 deg. F. again.

These curves were obtained in a similar manner to those shown before and showing incidentally the rapidity of cooling this section in an oil at 70 deg. F. of about 100 Viscosity (Saybolt at 100 deg. F.). Also the Brinell hardness taken at the outside of the threads is in each case 512. The oil we use for quenching is a mixture of 70 vis. paraffin and 180 vis. Red Oil, the blend having a flash point of 310-330 deg. F.

If we examine a worm hardened at 1540 deg. F. for even 10 to 11 minutes we find the hardness at the center to be about 500 Brinell, but if we examine the center of a worm hardened at 1540 deg. and then reharden again at 1540 deg. F. for 7 minutes, we find it to be about 340 Brinell and the curve obtained by a transverse test of such a worm shows greater ductility than the one hardened clear through (see figure 10). This, as can readily be seen, represents far better physical properties than either a case hardened worm or a worm hardened through, figures 2 and 3.

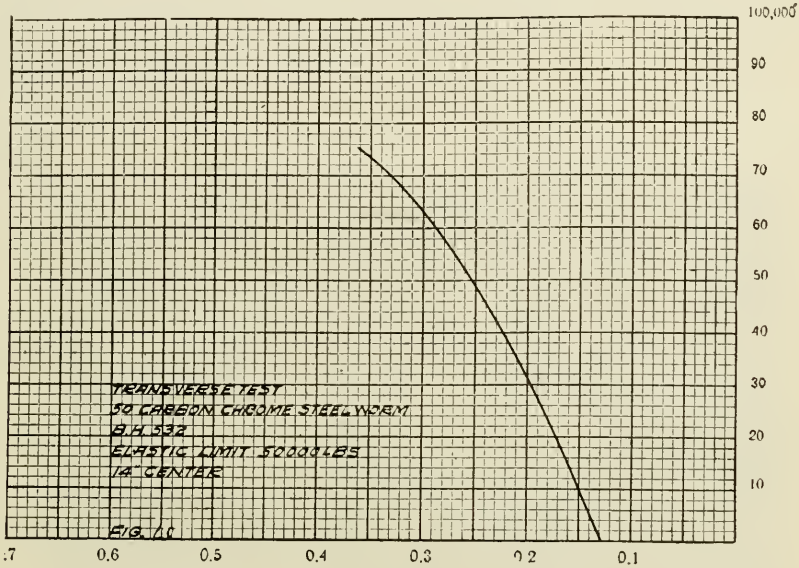


Figure No. 10

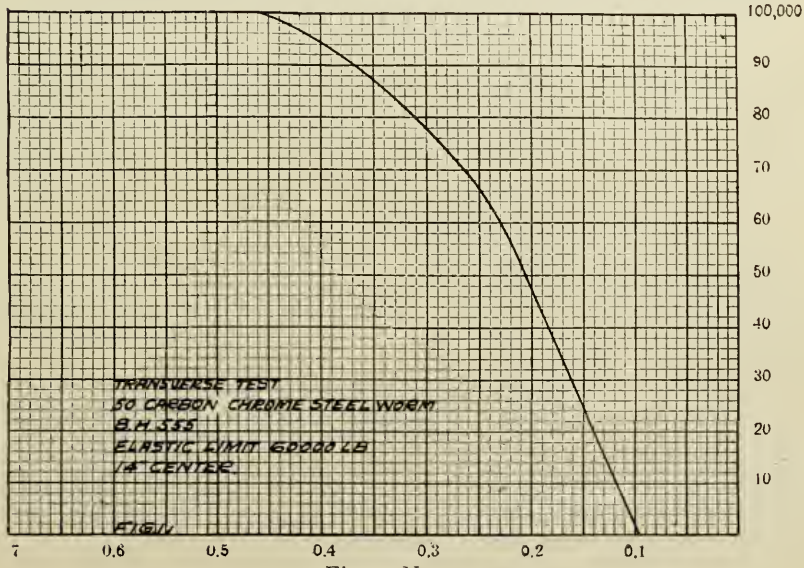


Figure No. 11

This heating time, however, is extremely low and makes handling of the pieces rather difficult, so the curve shown as a dashed line was run with a furnace temperature of 1470 deg. F., and in order to obtain the same temperature at the center of the worm using these conditions, it is necessary to allow the piece to remain in the bath 12 minutes. This temperature, as you will note, gives us the same hardness on the outside as the other, but the center of the worm is not brought up to a hardening heat. An inspection of this worm shows a Brinell of about 340 at the center and 500 throughout the tooth section.

So by treating the worm at the required temperature to harden it all the way through and rehardening it at a lower temperature for a shorter time we obtain a worm in which the hardness throughout the teeth is over 500 Brinell and the core or center of the worm is about 340 Brinell. This gives us a worm whose stress strain curve is shown in figure 11.

The effect of other heating media than the two cited before is brought out by curves fig 12. This shows the heating time of a worm heated in an

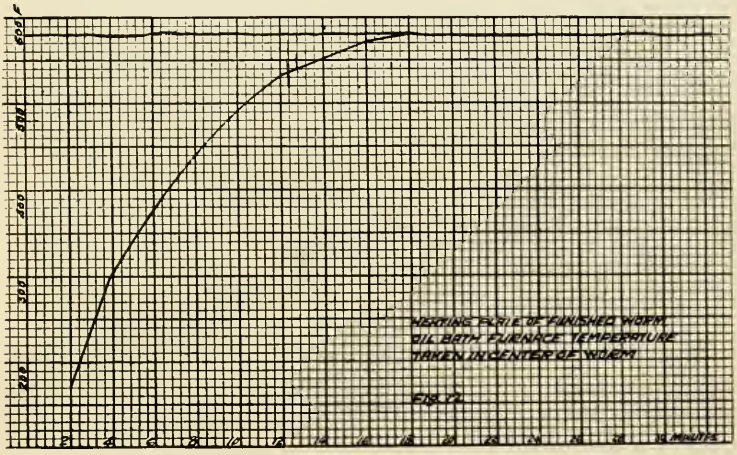


Figure No. 12

oil bath maintained at a temperature 580 deg. F. In this case the furnace temperature was obtained by means of a mercural thermo-meter and the center of the worm temperature by means of a thermo-couple described before. These show the advantages to be derived from a critical study of thermal curves. The work involves no particular extensive layout of apparatus and proves of inestimable value.

DISCUSSION OF MR. McCLOUD'S PAPER

Mr. McCloud: Mr. Chairman and Members of the American Society for Steel Treating—(Reads report, illustrating with slides). Interjects following remarks:

Another point of some interest on these curves is the position of the thermo-couple lag on cooling. You see it is very plainly marked in both curves, some slight differences on the tube, but not particularly bad. The temperature in the one case is about 1240. The slides aren't very good, so you cannot see the position of the ordinates, but this is the 1200 line, and that is the 1300 line, 1300 degrees Fahrenheit, so you see in this case it is 1240 and and in this case possibly 1250 degrees.

Figure 2 is a chart of the stress strain diagram obtained on an Olsen

Testing Machine of a finished tractor worm tested on 14" centers, transverse stress. The curve goes up and the elastic limit is just beyond the 40,000 pound mark. It runs up to this point, and from that point right straight on until failure occurred a little ways over.

That last curve was on a piece of .20 carbon chrome vanadium steel worm case hardened, about 1/32-inch deep.

This curve is that of a high carbon, that is, a .50 carbon, chrome steel, and hardened all the way through. The brinnel is about 500 in the center, as well as on the outside. You will note that the elastic limit, of course, practically coincides with the ultimate point up here at seventy thousand pounds. To be sure, it is nearly double that of a case hardened worm, but its deformation beyond the elastic limit was nil. In other words, it broke right off short.

Figure 5 shows the heating time to this point. This shows the beginning of the curve.

Figure 6. The next curve shows the heating time of a worm in an air furnace at 1600° F. In this case the heating time is 36 minutes, whereas in the other case it was 40 minutes. I had plotted on here the furnace temperature as well as the temperature of the center of the worm. The right hand curve shows the temperature of the furnace taken with a platinum-rhodium thermo-couple, and an Englehardt Milli-voltmeter. The lower line shows the temperature in the center of the worms, finished worms, in these cases, taken with a similar couple and a Leeds & Northrup potentiometer.

I just want to call attention to the difference in the heating time of the finished worm when the furnace temperature was maintained in one case to 1540, and in the other case to 1600. When the furnace temperature was just sixty degrees higher there was a difference in the heating time of four minutes. In both furnaces or both cases the furnace is at substantially the temperature the worms finally attained.

Figure 7. These lines here indicate the furnace temperature, and the other lines indicate the temperature in the center of the worm. I will point out that according to these curves the statement by Wagner, as I cited before, requires modification in certain instances.

We had to start out with a furnace temperature of considerably above 1600, because the heat stored in the furnace walls was not large. It was a laboratory furnace. The dark line shows the heating time with a furnace temperature of 1540 and the other line shows the heating time with a temperature of 1300 degrees.

The time required to bring the center of the forging to the temperature of 1200° F. is less when the furnace temperature is 1600 than it is when the furnace temperature is 1550° F.

In these cases you note the A. C. point is quite clearly defined as being 1350 degrees. Incidentally, that is about 100 degrees lower than that determined on a small piece by a differential method. I presume the difference was probably due to the mass, and I would explain it as representing the average critical point of the steel. In other words, the temperature of the outside was probably above the critical point.

Figure 8. This is just a differential curve, a critical point curve, taken on a piece of material of this analysis, showing the critical point on heating of 1420 to start, and an average of 1450, and on cooling a maximum difference in temperature of the nickel body and steel piece at 1280 degrees. These curves were taken in a molten salt bath furnace.

Figure 9. You will note in this case the curve with the solid line is the heating time for a worm, for the center of a finished worm, when the furnace temperature was maintained at 1540 degrees. You will see the furnace temperature is right along that line, and the other is for a furnace temperature of 1450 degrees. You will note that the worm when the furnace temperature is 1540 gets up to the heat of the furnace much faster than it does when the temperature is actually lower—at 1470.

These curves were taken in a similar manner to the ones before and, incidentally, show the rapidity of cooling of the worm in oil. We use the oil at a temperature of about 70° F., an oil of 100 viscosity, and it is a mixture of paraffin and oil having a flash point of 310 to 330° F. Also the brinnel hardness taken on the outside is, as indicated, 512 in both cases.

Figure 10. This is a transverse test of a worm and shows an elastic limit of around sixty thousand, and an ultimate strength of one hundred thousand, and a deflection of about .4 of an inch. In this particular curve the worm did not break. Our testing machine is only a one hundred thousand pound machine, and we find a great number of worms that we are unable to break.

Finishes paper and discussion. (Applause.)

Chairman: I know we have all listened with much interest to this question of the time and temperature, etc. There is no question but what there is considerable to be learned by studying these conditions and, of course, we can see their value, not only from the quality standpoint, but also from the production standpoint, which presumably, in most shops today, is a point of great importance.

Mr. Stagg: May I inquire from Mr. McCloud if the material on which he obtained his heating curves when he was working in production and material and the material that he obtained his heating curves from when he was working experimentally with the differential were one and the same lot or part of the same material. I am unable to reconcile a difference of 100 degrees in a critical temperature on the same material, under production methods and under experimental methods.

Mr. McCloud: It was not the same piece. It was a piece of the same material, it had the same chemical analysis, but was not the identical piece.

Mr. Stagg: May I ask you how you explain the difference?

Mr. McCloud: It is, as I attempted to explain it, I would say that the difference in the lag was due to the fact that in the case of the large piece we actually took the temperature of the center of the worm, whereas in the small piece you take substantially the temperature of the whole piece, and in the case of stock heated as rapidly as that was heated, the outside was at critical point considerably higher, and the mass of the steel, which determines the lag anyway, was considerably above the temperature of the center of the piece.

Mr. Stagg: I assumed that was going to be your explanation, but I wanted to be sure to bring out the salient point that the critical temperature is a constant in any material.

Mr. McCloud: Oh, yes, that is so.

Mr. Marshall: In my experience I have actually forced the critical range higher than it should be, and I can explain it in this way. The work was only touching the couple, and the couple caused a reaction from the reading temperature of the couple. In that way the temperature will get ahead of the temperature of the piece. I have seen a plain carbon steel with a critical range of 1375 occur as high as 1425.

Mr. Stagg: Which is the very converse of Mr. McCloud's statement. He was testing from the center of the piece and you were testing from the outside.

Mr. Hodge: I would like to ask if failures were frequent, and if so, what was the matter, that is, would the worm break transversely or the surface fail?

Mr. McCloud: The largest component of load in the case of a worm is transverse component. If you analyze the stresses on a worm you will find that while there are several applications of stress, the stress which brings the greatest fiber strain on the material is the transverse load, and in the case of worms that are hardened clear through we had instances of failures, and the failures were all transverse fractures. Sometimes we would have a little trouble with the surface of the worm in grinding on account of carbonizing a worm, but that has been the only surface trouble that we have run into. You see, the tendency is always to push the grinding a little bit too hard, and if trouble starts in the case, of course it is made worse during the use of it.

Mr. Hodge: What I was trying to bring out particularly is as to carbonizing the worm. That is, a carbonized worm, leading to the core, would never fail under transverse load, or would never break, if properly heat treated. I imagine the trouble in that case would be in throwing out of line and poor measurement. I wondered if that actually occurred.

Mr. McCloud: I don't recall any cases of failure or carbonized worms other than surface troubles that I spoke of before, and I personally believe that all that trouble was traceable to the condition of the material as it was ground or right after it was ground. One of the biggest factors that decided us to attempt oil-hardened stock was the saving we believed we could effect in production.

Mr. Marshall: I would like to ask if there were any deleterious effects noticed due to introducing the steel into a hot furnace.

Mr. McCloud: I can't say I have ever seen any that I would explain in that way.

Mr. Marshall: No effect on the outside surface of the worm?

Mr. McCloud: No.

Member: I would like to ask Mr. McCloud if he noticed any difference in the time of heating with the difference in fuels used in the furnace at the same temperature.

Mr. McCloud: I cannot say as I have, and it hardly seems to me, offhand, that you would note any difference under conditions such as I cited. Of course, I refer the most particularly to that curve that showed the heating time in the molten salt bath furnace. The method of heating is by conduction from the bath of salt, and maintaining the furnace at a given temperature, I can scarcely see how you could affect at all the heating rate, through using different fuels.

Member: For several years we have noticed a difference in time of heating with the different fuels at the same temperature, but nothing definite has been hit upon by men of your ability or your opportunities in those directions, and it is just in that connection that in some heat-treating plants where they have used an oil fuel and have changed to a gaseous fuel that the time of heating has been very materially decreased, and with the same temperature of the furnace.

Mr. McCloud: I might explain a little bit better what I mean by that. The curves taken in a molten salt bath furnace were taken of a single worm put in a cyanide box about sixteen inches in diameter and about the same in depth, and the curves showed that the drop in temperature of the furnace was negligible when the piece was put in, and the curves that showed the heating time in the electric muffle, which was not particularly large, and a forging that size took up a great deal of the heat of the walls of the furnace, consequently, under such conditions as that, probably the heating time would be affected by the fuel used, but where you use a molten salt bath furnace under the conditions that we give it, the drop in temperature would be negligible.

DISCUSSION OF MR. T. D. LYNCH'S PAPER

Article Published in October, Page 62, Vol. 1, No. 1.

Chairman: I am sure it is with a great deal of interest that we have listened to this very excellent paper by Mr. Lynch. As he began reading certain clauses of the specifications, it took me back to the busy days of two or three years ago when all of us were either busy preparing certain specifications or being told how absurd certain things that we prepared were. The things that I wondered regarding the specifications which he has prepared are whether or not these specifications have been submitted to a steel mill, and if so, if they are thoroughly in accord with them and are willing to cooperate and produce material in accordance with them.

Mr. Stagg: Regarding the request of the professor as to whether a steel mill will meet these specifications, I am not quite sure, but I wouldn't be a bit surprised if Mr. Lynch didn't have to visit some steel mill and see their practice and incorporate their practice in his specifications.

Mr. Cook (member): Mr. Lynch pointed out that the engineer and the metallurgist and others should coordinate. I think he really forgot the cost department. I was just wondering how much he would have to pay per pound to meet such specifications.

On the other hand, I think it is certainly very well put together, and the only possible flaw to make it thoroughly complete would be the point of heating up the ingots. In silicon steels such as he mentioned he said the silicon should be about two per cent. One very important point is the rate of heating up of the ingots before they are rolled. That is one of the principal causes in bringing about flaws and defects in high silicon steels.

Mr. McCloud: I have been interested in specifications on a somewhat smaller sized spring that requires a great deal of care. I should like to ask Mr. Lynch an expression of opinion as to whether or not it is advisable to incorporate in the specifications the closing pressure to some pre-determined height as well as the free height of the spring, or whether either one or both of them should be included. I don't know whether you understand me or not, but, supposing the spring is not stressed, it is designed so it will not be stressed beyond its elastic limit. It would be possible really to produce, to specify a spring either according to its pressure at a given height or according to its free height, specifying the size of the wire, for instance, or whether it is advisable to put in both.

Mr. Lynch: The question of the design of springs is one that is a very large one and it has been, I should say, dependent very much on the use

you are going to put the springs to, as to what sort of tests you are going to put them to. In this particular picture or application, his application is run so it is perhaps necessary for the spring to become closed on certain conditions, because it cannot go its limit, whereas other springs would not be limited; they can be compressed beyond their elastic limit, and not be in an entirely enclosed position. As far as the other question is concerned about the material, this has been made, and the steel makers and spring makers have been very courteous in working out these problems, and we have a good many of those springs in service. The paper was not read so much to bring out the point of the application as it is to bring out the application of springs in severe service in various places, because the locomotive people are having a great deal of trouble with springs breaking in service, and they want a higher quality of spring, even at very much increased cost. The first cost of a spring is not always the whole story, because, if a spring breaks, it costs so much to put the locomotive out of commission and until a new spring is obtained, so the first cost is not the whole cost, and the whole cost, if it is the entire cost, brings it down to a proportional proposition.

Mr. Birkbeck: You spoke about 150 points of silicon. Do you think that is good policy?

Mr. Lynch: I think we want uniformity; we want to know what we have. We might be able to work it out at 150; 220 is the standard recognized by steel makers. I would like to state in this connection that in working out specifications we have always found it very desirable to take as nearly what is already commercial and embody that rather than to attempt to get up something that is new, that is, so we do coordinate with the steel makers, and use their mill practice just as closely as we can, and the fellows that don't line up and give us good uniform results—train them and get them to the point where they will line up and give us those results. In this case the spring manufacturers are lining up.

Mr. Kaufmann: I want to ask you why you limit specifications only to crucible and electric processes.

Mr. Lynch: There is another case where we want the best product we can get, and we have every reason to believe we can get a more uniform product either in the crucible or the electric furnace than we do in the open hearth, especially in the large open hearth heater. The people that are manufacturing open hearth steel as a rule don't take the same care in the manufacturing of the steel as the man who makes it in smaller quantities in the crucible or in the electric furnace. It is quality we are after, rather than quantity.

Mr. Johnson: I would like to ask Mr. Lynch what are the best tensile figures he has found so far on his silicon-manganese steel. Those that he would consider the most ideal thus far.

Mr. Lynch: Mr. Chairman, we would like the tensile to run 200,000 pounds or better, and I have not gone into that end of it so thoroughly as I would like to. I shouldn't wonder if Mr. Stagg couldn't enlighten us on that, because he has been kind enough to help treat some of this product. He has helped me a great deal in working out this problem. We have been checking very closely on the brinnel tests rather than on the physical or full tensile tests.

Mr. Stanger: I would like to ask a question. I have never been able to satisfy my own mind what the answer is. It is in reference to silico-

manganese steel. If we take silico-manganese steel made by the electric furnace and made by the open hearth process and the steel has the same composition, give it the same quenching temperature and the same quenching medium, we find that we get equal brinnel hardness, but we have to draw the open hearth steel about one hundred degrees Fahrenheit higher than we do the silico-manganese steel that is made by the electric furnace. I would like to have an answer to that if anyone here can give it; I have never been able to satisfy myself as to this difference and the reason for it.

Prof. Harder: I would like to inquire of the author if he tried to get sufficient hardness working at somewhat lower temperature, 850 to 875. and if he was not able to get it with the lower temperature, what type of oil he uses, especially with regard to classification as a heavy oil or a light oil.

Mr. Stanger: We used a light oil, comparatively speaking. As far as that is concerned, the quenching speed of oils on some tests we made a year ago would indicate it doesn't make very much difference.

HEAT FLOW THROUGH FURNACE WALLS

E. F. Davis.*

A paper presented at Philadelphia Convention.

PART II. (Conclusion)

Assume that you have a heat-treating furnace to build and that you wish to make the walls 13½″ thick and temperature of 1600° F., the room temperature is %° F. What advantage would there be over a furnace wall composed of 13½″ of firebrick by one of the same thickness consisting of 9″ of firebrick and 4½″ of Sil-O-Cel.

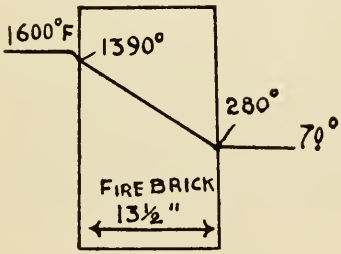


Fig. 1

Air Temp. Diff.—1600—70=1530° F.

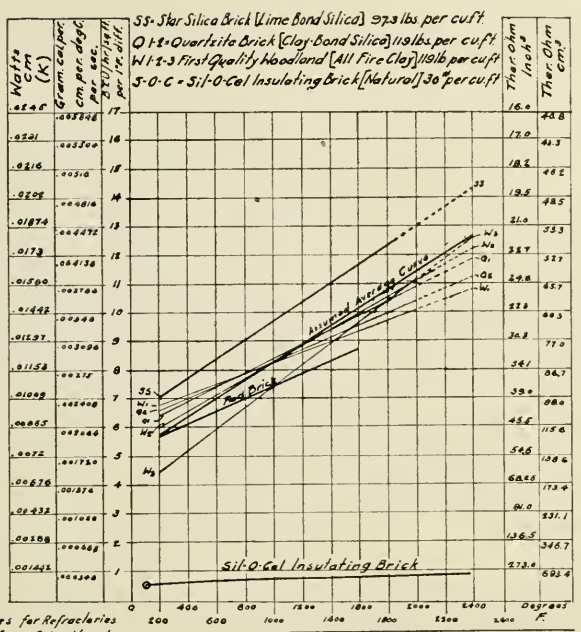
Average internal conductivity of firebrick at 1600—70=835°. Mean temperature equals, according to B. Dudley, Jr., tests at Pennsylvania State College 7.9 B. T. U. per square foot per hour per 1″ thick for 13½″, the heat flow would be

$$\frac{7.9}{13.5} = 0.5852 \text{ B.T.U. per deg. temp. diff.}$$

This difference must be: $\frac{755.35}{0.5852} = 1290.8$ deg., which deducted from 1530 deg. leaves 239.2 deg. for temperature drops at the two faces, or 119.6 deg. on each surface. The required heat emission factor would, therefore, have to be

$$\frac{755.35}{117.6} = 6.32 \text{ B.T.U.}$$

*Sales Engineer, Celite Products Co.



Figures for Refractories taken from B Dudley Jr. Tran. Amer Electrochemical Society 1915. That for Sil-O-Cel from Bureau of Standards at temperature indicated ⊙

Fig. No. 5

In reality the emission factor at this difference cannot exceed 2.2 B.T.U. Therefore the temperature drops at the surfaces must be more than 119.6 degrees, and the surface temperature difference less than 1290 degrees and the whole heat less than .753 B.T.U. per hour.

After a number of trials of such temperature drops are obtained as satisfy the various known relations, factors of heat emission at the various surface temperature differences being derived from L. B. McWilliams' test of pipe coverings (*A. S. M. E. Journal*, Jan., 1916) and *Power*, April 9, 1916. Assuming constant conditions, the rate of receiving, transmitting and emitting heat from a square foot of wall per hour is as follows.

At hot side.....	210 deg. × 3.093	649.5 B.T.U.
Through wall.....	1,110 deg. × 0.5852	649.5 B.T.U.
At cool side.....	210 deg. × 3.093	640.5 B.T.U.
Total.....	1,530 deg. air temp. diff.	

The heat loss per square foot per 10 hours under the conditions stated is, therefore, 6495 B.T.U. not 7554 B.T.U. The ratio is as 86 to 100.

A more accurate determination of the true heat loss is somewhat tedious, because the heat conductivities vary with the mean temperature which are not known. In addition, the total heat flow is governed by the surface temperatures, which also are not given. In the absence of charts the results must be found by successive approximations.

Assuming the internal conductivities of the wall to be—

$$H = \frac{1}{\frac{9}{9.4} \quad \frac{4.5}{.65}} = .127 \text{ B.T.U. per degree.}$$

The rates of heat flow per square foot per hour are found to be:

At hot side.....	86 deg. × 2.0	— 172 B.T.U.
Through wall.....	1,358 deg. × .127	— 172 B.T.U.
At cool side.....	86 deg. × 2.0	— 172 B.T.U.

1358° is found by referring to Fig. 2, which shows a drop for inside

and outside of surface to be 1258°. The 86° is found by subtracting 1358 for (1600 — 70) which equals 172, half of this is 86° or the temperature drop on each surface.

Fig. shows the temperature gradients by this method.

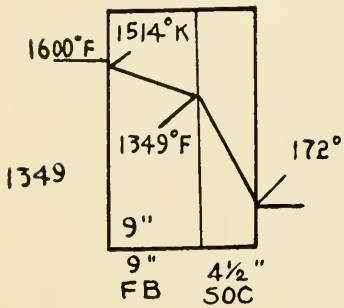


Fig. 2

Temperature gradients through wall.

1600° — (172 × 1/2 = 86) = 1514°
1514° — (172 × 9/9.4 = 165) = 1349°
1349° — (172 × 4.5/.65 = 1193) = 156°
156° — (172 × 1/2 = 86) = 70°

It will be noted that the temperature drop per inch through the firebrick was approximately 24° and through the SOC 265°. This amounts to approximately ten to one, but it is the belief of the writer that this is rather high. Six or seven to one being nearer correct in practice. The method shown in this calculation, however, is correct.

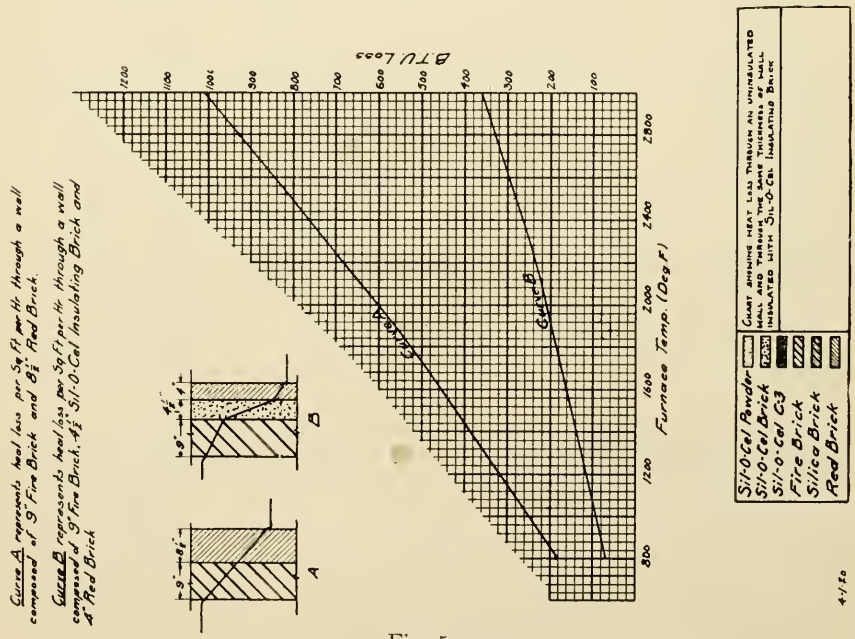


Fig. 5

Advantages of Insulation

The advantages accruing through the right method and character of insulation are many. Considering again furnace walls as a matter of illustration, the accompanying diagram (Fig. 1) sets forth conventional insulated and uninsulated walls, giving a typical example of the effect of insulation when applied to the wall of the heated equipment and regardless of the exact nature of that equipment.

Taking an internal temperature of 1600° F., and a surrounding atmospheric temperature of 70°, the exterior uninsulated wall shows a temper-

ature of 280° as against 156°, with an insulated wall. The insulated walls, as will be noted, consist of 9″ of firebrick, 4½″ of insulating brick; while the uninsulated walls are composed of 13½″ of firebrick.

The resulting fuel saving is also shown in the figure, based on 1,000 square feet per hour of radiating surfaces, and utilizing coal, oil and gas, respectively, as fuel. It is found that the insulated walls saves 38 lbs. of coal, 3.1 gals. of oil, or 757 cu. ft. of gas per 1,000 sq. ft. per hour radiating surface, in accordance with the different character of fuel. And further, it is interesting to note that the B.T.U. saving amounts to approximately 70% of the heat lost through the uninsulated walls.

This is but an ordinary example of what can be accomplished with proper insulation. It illustrates in a striking manner just what is going on with uninsulated equipment in the heat-treating plants; it points out a comparison of losses and shows, generally speaking, how such losses can be corrected. This heat, so lost ordinarily, should be put to productive use, and in putting this heat to work lies the greatest benefit of insulation, for it enables us to speed up production without increasing equipment, and hence lowers production cost through a decreased overhead.

Insulation of a Large Annealing Furnace

The following is the method used in the insulation of an annealing furnace:

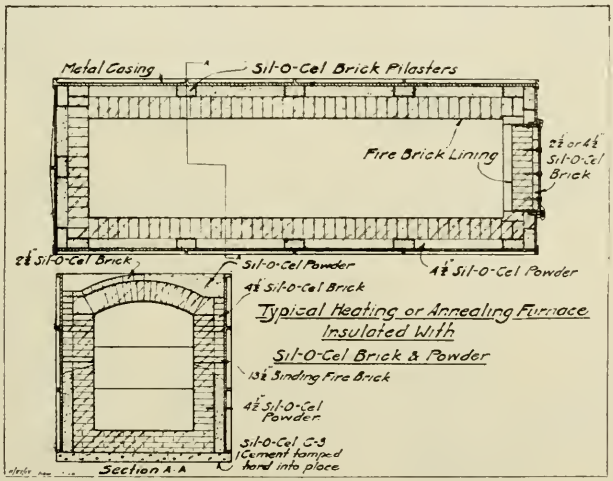


Fig. 6-A

Below the floor line, between the flues, the ground is well tamped and there are two courses of three-inch tiles with broken joints layed down as a foundation. Over this is one inch of grogg. On top of this two and one-half inches of Sil-O-Cel brick. Over the Sil-O-Cel brick from three-fourths to one inch of grogg, and on top of this or on what is called the furnace floor, are three inches of vitrified firebrick flooring.

The side wall construction is very rigid and substantial. It consists of cast iron channels with the flanges drawn in. The channel is approximately one inch thick. The flanges are about four inches. A course of red brick to a thickness of four and one-half inches is layed up against the channels, which is supported from the outside by very strong stays. Next to the red brick are four and one-half inches of Sil-O-Cel brick and then

9 inches of best No. 1 firebrick obtainable. The firebrick and redbrick are bonded through the Sil-O-Cel brick at intervals of three or four bricks, every fifth course staggered.

They want rigid construction, as the side walls carry the arch, which contains Sil-O-Cel brick. The rear wall is being insulated the same as the side walls. The furnaces are fed from the rear. There are two doors, in cast iron form, to each furnace, size approximately six feet wide, nine feet high and approximately nine inches thick. The furnace is approximately 12 ft. by 12 ft.

The arch, inside dimensions, has a radius of 11 feet, while the outer dimensions are eight feet six. The doors are removed by an electric crane operating over the furnace. Just now the doors contain 9 inches of firebrick, but in the future will have C3. The temperature here never exceds 1800° F.

Insulation of Rotary Type Furnace Carbonizing

One of the largest manufacturers of gears has recently had installed and put into successful operation a furnace for carburizing that should be of interest to all users of heat-treating equipment. This furnace was designed and erected by Tate-Jones & Co., Inc., Pittsburgh.

Although the principle has been incorporated in a few furnaces now in operation, the design of this furnace is new and original, and is of the Rotary or Rotating Hearth Type, as shown in Fig. 7. Oil is the fuel used.

The general shape of the furnace is shown. The revolving carriage or hearth is 16 ft. 6 in. outside diameter and 6 ft. 6 in. inside, having a width of 5 ft. 0 in. and revolves on wheels set in the foundation. The furnace is 19 ft. 0 in. over all, and is insulated as follows:

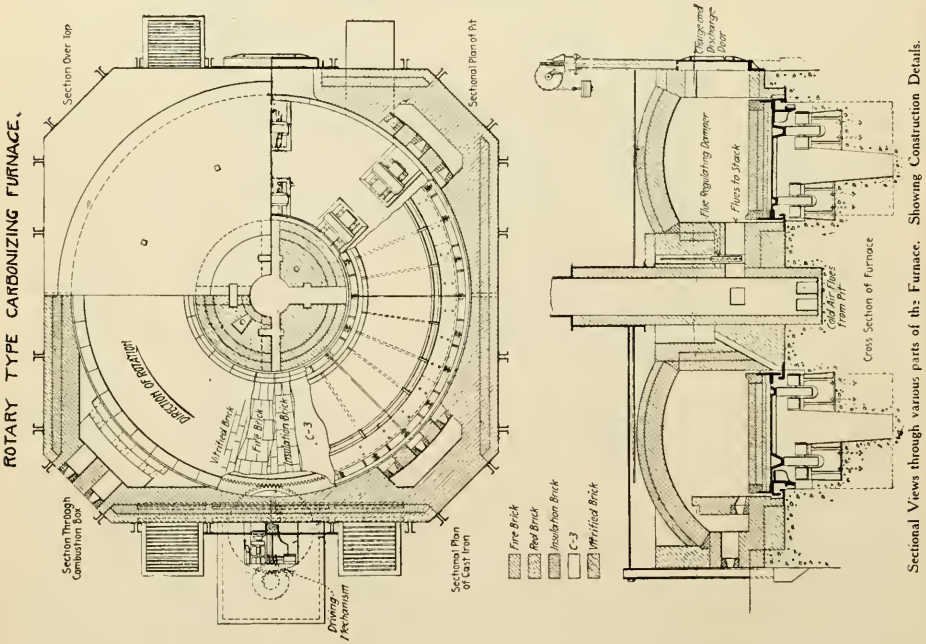


Fig. No. 7

The top of the furnace is insulated with Sil-O-Cel.
The side walls are insulated with 4½ in. Sil-O-Cel brick.

Burners at the four corners fire into combustion chambers and the heat is led from these so as to be evenly distributed over the hearth, and finally is vented to the center and is carried out of the building by a stack.

Power to drive the hearth is derived from an electric motor which is geared down so that the hearth makes one revolution in the time required for carburizing. This gearing is so devised that the time of revolution can be regulated varying from 6 to 12 hours in steps of 15 minutes.

The sand seal around the edge of the revolving carriage was removed and Sil-O-Cel C-3 powder substituted because the sand offered too much friction and conducted the heat away.

The hearth is insulated with 4-in. Sil-O-Cel C-3 and temperatures around the running gear have not exceeded 300° F., even after weeks of continuous operation.

The saving over a similar furnace not insulated is 20% of the fuel.

Methods of Insulation by Various Furnace Manufacturers

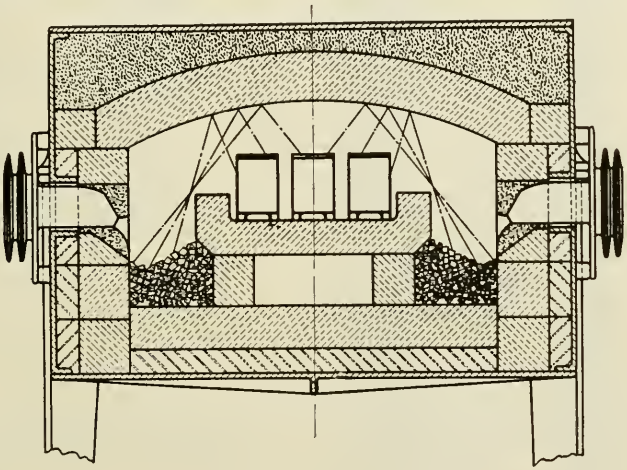


Fig. 8

Fig. 8 shows method used by the Surface Combustion Company to insulate their heat-treating furnaces. Sil-O-Cel powder is placed in the upper part of the furnace over the firebrick arch and standard Sil-O-Cel split

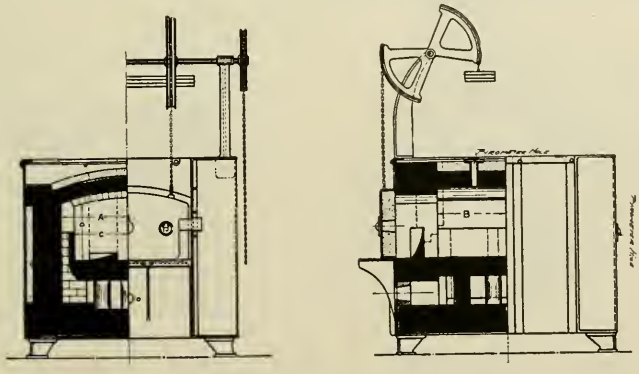


Fig. 9.

9 x 4½ x 1½ and placed in the side walls and bottom of the furnace next to the outer shell or casting.

Fig. 9 shows a car type furnace made by the Tate Jones Company and the method in which they use Sil-O-Cel for insulation. Two and one-half-inch Sil-O-Cel brick is used over the arch, 4 in. of C-3 or calcined.

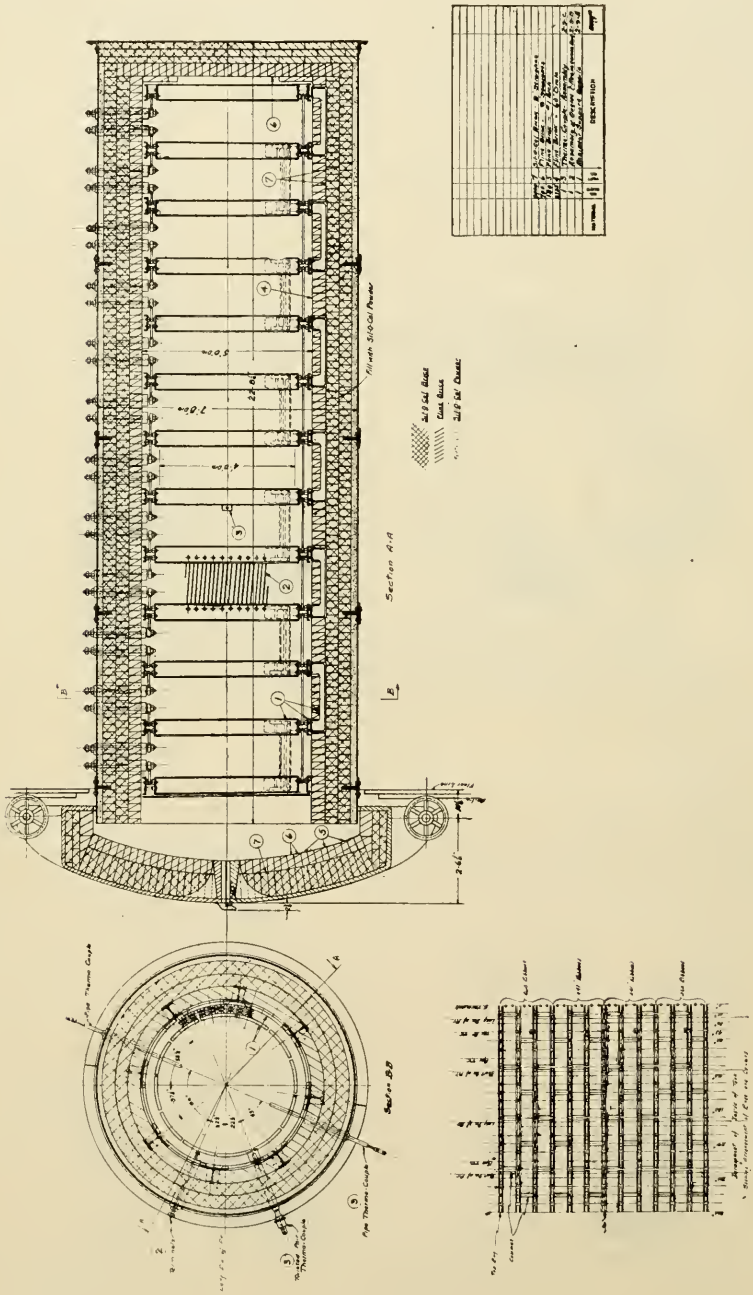


Fig. 10

Sil-O-Cel under the firebrick hearth in the car. A minimum of 4 in. of C-3 is used in all their doors.

Fig. 10 shows the method used by the American Metallurgical Corporation to insulate their electric furnaces. The above photo shows that the construction of this furnace is as follows: 4½ in. of firebrick, 9 in. of C-22 calcined Sil-O-Cel brick and 2 in. of Sil-O-Cel powder rammed between the brick and the outer shell.

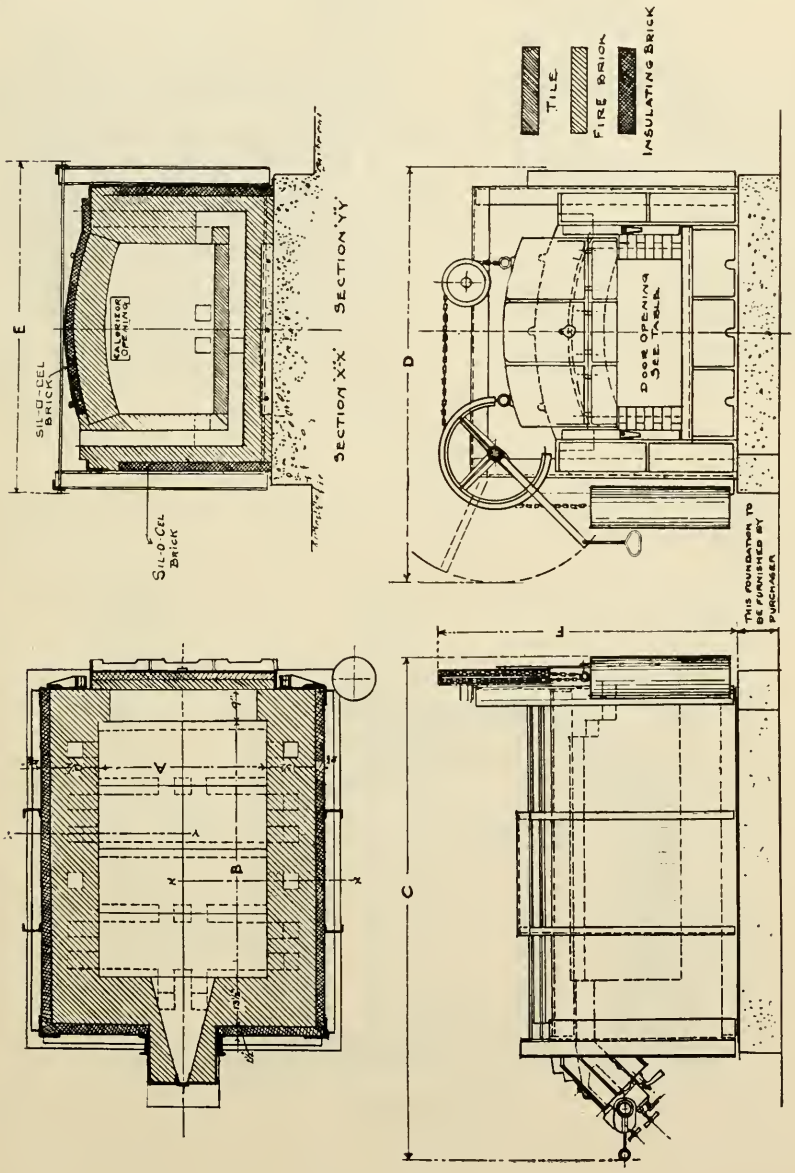


Fig. 11.

Fig. 11 shows cross section of a car type furnace manufactured by the Mahr Mfg. Co., and you will note that Sil-O-Cel brick is used in the side

walls and over the arch of these furnaces, 2½ in. thick. On the car under the firebrick part 2½ in. of Sil-O-Cel C-3 is used. In the doors a course of Sil-O-Cel brick 2½ in. thick is layed back of the firebrick, which prevents loss through radiation, which is always a big item in heat-treating furnaces.

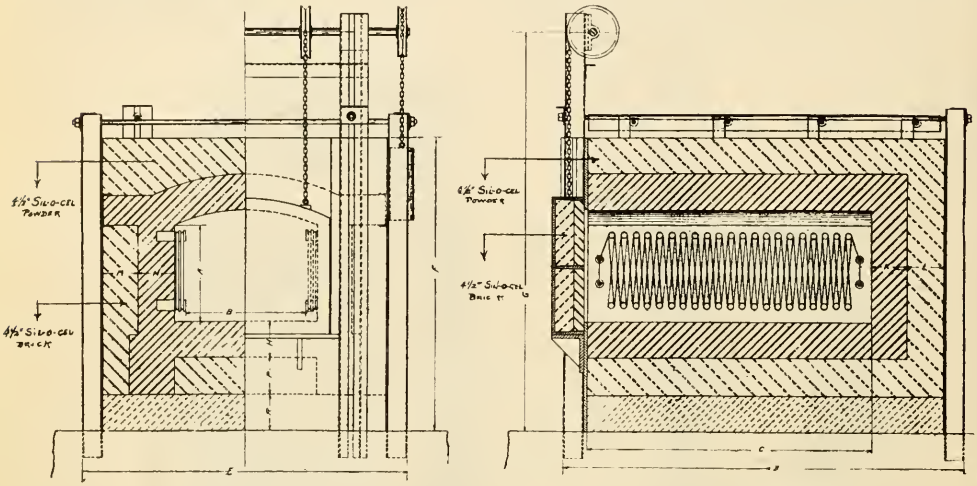


Fig. 13.

Fig. 13 shows the method used by Geo. J. Hagan Company to insulate their heat-treating furnaces with Sil-O-Cel standard insulating brick and powder.

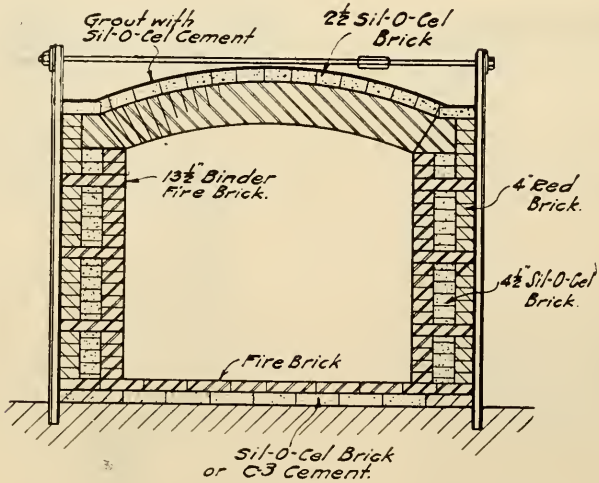


Fig. 14.

Fig. 14 shows a cross section of the general methods used by Tate Jones Company to insulate their standard heat-treating furnaces with Sil-O-Cel brick, Sil-O-Cel powder and Sil-O-Cel C-3 in their furnace doors.

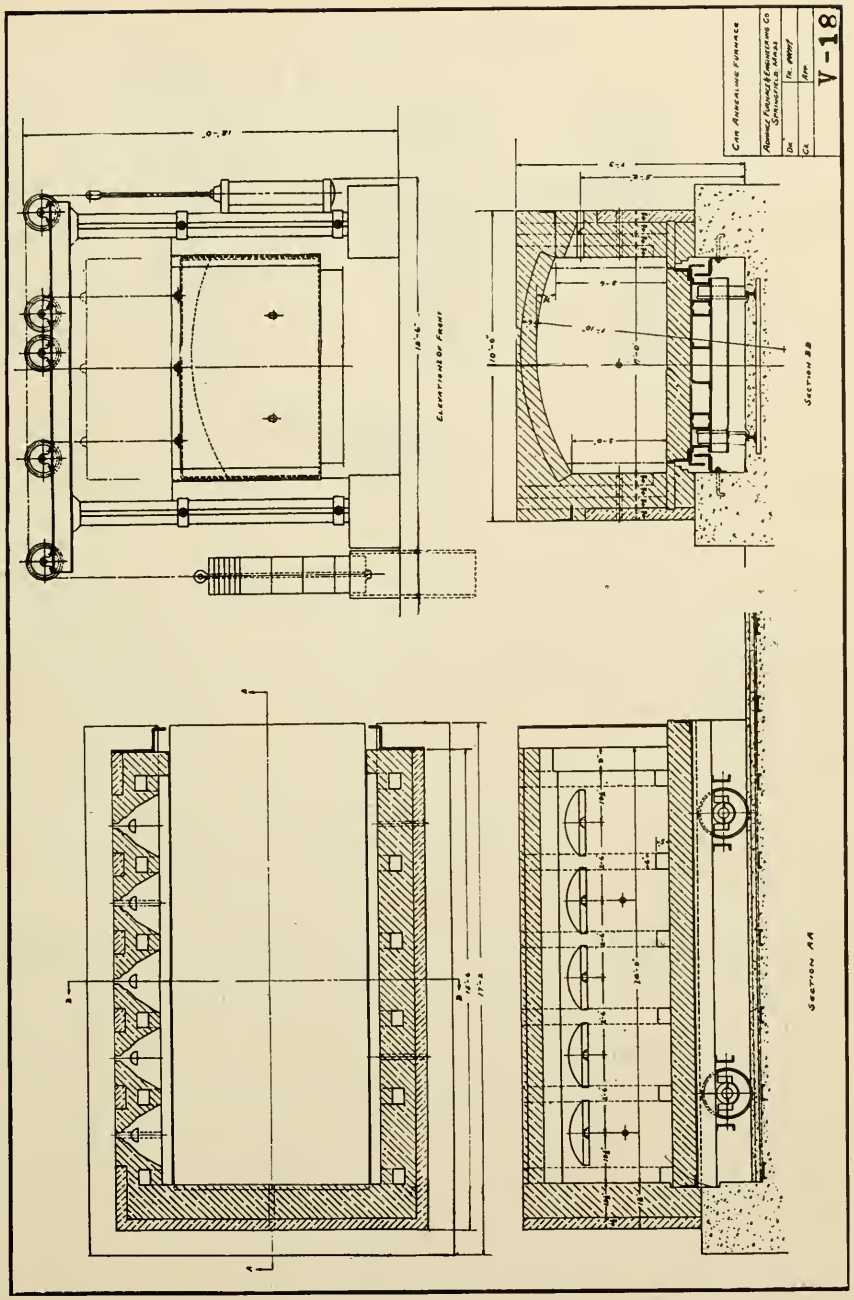


Fig. 16.

Fig. 16 shows a cross section of an electric heat-treating furnace made by the American Metallurgical Corp. This cut shows the use of the C-33 calcined Sil-O-Cel for the middle wall.

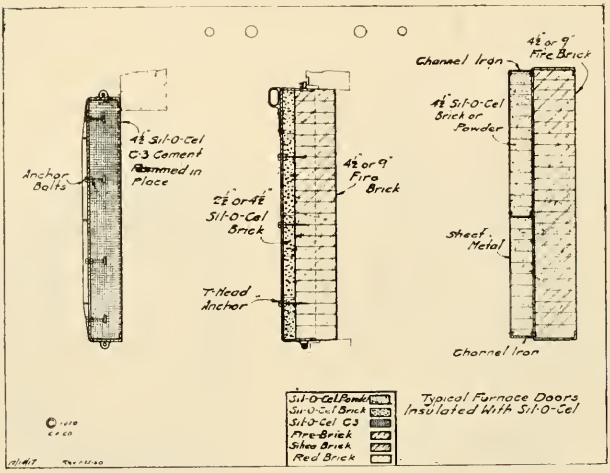


Fig. 17.

Showing use of C-3 in Furnace Doors

Comparative tests have been made between Sil-O-Cel C-3 and firebrick as to the cost of labor and material and it has been shown in a number of cases that Sil-O-Cel is 50 to 75 per cent cheaper to apply, also the life is considerably longer and approximately 50 per cent of the heat lost through the doors when lined with firebrick is saved when Sil-O-Cel C-3 is used as an insulator.

Small furnace doors less than 2 ft. in any dimension do not require reinforcing.

Furnace doors used in annealing and heat-treating furnaces which are larger than 2 ft. in any dimension require tie rods as reinforcements. These tie rods are run vertically and horizontally, placed not greater than 18 in. apart.

In doors of this kind it is advisable that poultry wire of 1-inch mesh be used as a reinforcing. This is generally placed between the intersections of the tie rods. In all instances reinforcing should be kept close to the center of the door, as it keeps the tie rods far enough from the hot surface of the door to avoid expansion.

Wherever it is desired to project the insulating lining, it is advisable to use a course of fire brick on edge completely around the door up against the steel, letting these bricks protrude past the steel, giving the desired projection. The C-3 lining is then finished up flush with the edge of the brick.

Peep holes are very easily put in this type of door by filling in around a core the desired size when filling in the door.

Furnace Doors

Furnace doors, as a rule, have been heretofore lined with firebrick from 2½ in. to 9 in. thick. On doors of this kind the brick must be properly wedged in—this necessitates a great deal of cutting of the firebrick. By laying these doors on the floor, turned up as a mould, they can be easily and quickly filled with Sil-O-Cel C-3 cement, which has previously been mixed with 20% by volume of Portland cement, thus cutting down labor costs.

An Annealing Medium

The annealing operation in general is carried out by heating the products to the required temperature and then cooling them in a pit of convenient size, filled with this powder. Such an annealing bed in service is shown in one of the illustrations. The pit is constructed of firebrick to such depth as required and to a height of about four courses of brick above the floor line. The annealing pit is directly opposite the furnaces, with a traveling crane available for conveying heavy parts from the heating furnaces to the powder bed.

In operation the heated metal product is immersed in a bath of the powder ranging from 6 to 8 in. in depth and deeper, depending upon the size of the casting and the rate at which the cooling is to be effected. After the required cooling point has been reached, the product is removed from the bath and worked in subsequent operations in the usual way. The rate of cooling, as will be understood, is dependent upon the depth of the powder and the construction of the pit. The lightness of the powder permits the heavy metal parts dropped into it to bury themselves rapidly where the bed will allow. To facilitate the handling of small castings and forgings, the powder can be used in small iron pots, boxes or other containers. As in the case of the larger parts, the castings are dropped into the bath after being heated in the furnace and allowed to cool. The powder is removed readily from the part as it is taken from the pit by simply brushing the surface, making it immediately available for machining or other operation.

This powder can be used indefinitely for annealing work. There are plants today which are utilizing supplies that have been in service for two years or more, with the material changing in color from its original white to a reddish pink. In this, it is stated by users, the powder bed really grows better and more effective in its ability for annealing work as the term of service expands, the moisture in combination being driven off and the resultant dryness enhancing the working value.

Beyond this feature of economy the powder makes for slow and absolute uniformity in cooling, eliminating any cooling strains on the parts annealed, with freedom from hard spots on the product. Moreover, it prevents the formation of any scale blemishes incident to the oxidation of the heated part, and in the case of medium carbon chrome steel parts it bars serious cracking of the material. The use of this powder also eliminates any necessity for reheating the furnace, allowing for continuous use of equipment with conservation of fuel and increased output.

Its Utility for Different Products

To afford a comprehensive idea of the use of Sil-O-Cel powder in various mechanical plants and its service for annealing products of different character, the following is cited: At a large works manufacturing differential gears for automobiles, various gear forgings are annealed, heating the parts to the required temperature and placing in a bed of the powder until cold. Different tools and tool steels are annealed in the same way, utilizing the powder instead of mica dust. For chrome-nickel steel gears this company uses a pit 8 ft. wide, 20 ft. long and 24 in. deep, constructed of firebrick laid so as to give a wall 4½ in. thick. Gears of this type are left in the powder bath from 18 to 24 hours and are then removed thence for the machine operations.

A New England machine tool plant, specializing in the production of automatic screw machines, uses a bed of this powder for treating carbon

and high-speed steel castings. In this the material is heated to the proper temperature in the furnace, under open fire annealing, and buried in the powder. It requires about 24 hours for parts of this nature to cool. Chrome-vanadium steel, intricate parts, clutches and kindred specialties are being handled with great success in these powder pits at this plant.

The annealing, both of iron and steel castings, is being carried on in a Western Iron & Steel Works by the use of this powder. Castings weighing from 30 to 80 lbs. are treated in this way, entirely covered with the material to provide gradual cooling. Parts heated to 1600° Fahr. are cooled in these pits and perfectly annealed. Beds as large as 5 ft. or more are in service, conveniently located so that overhead traveling cranes can drop the heated parts rapidly. Hydrated lime and graphite were used previously at this plant or similar service.

FACTORS LIMITING THE USE OF MATERIALS

Ira T. Hook*

A Paper Presented at Philadelphia Convention.

Introduction: As a military commander of a besieged city seeks to determine the strength of the forces limiting him to the encompassed city, so it is necessary for the engineer to take an occasional survey of the factors limiting him in his applications of forces and materials. With this purpose in mind the writer seeks to point out and summarize these limiting factors for the more common materials of construction.

List of Materials: A fairly complete list of the ordinary materials of construction now in use may be given in seven general groups.

(1) Wood, including paper and various materials made from wood fibre.

(2) Fibrous materials, including the ordinary textiles, hemp, manilla and jute fibres and asbestos.

(3) Stone and clays, including brick, cement, concrete and glass.

(4) Ferrous metals, steel, cast iron, malleable iron, etc.

(5) Copper alloys, brasses, bronzes and other compositions.

(6) Lead, tin, antimony, bearing metals and similar alloys.

(7) Aluminum and other light allows.

Properties of Materials: These materials all have their weak points and their peculiar advantages. A general discussion of properties of materials would embrace the following subjects:

Strength.
Low cost.
Workability or machinability.
Heaviness or lightness.
Toughness
Hardness.
Uniformity of structure.
Resistance to chemical action.
Resistance to high or low temperature.
Resistance to moisture.
Resistance to animal life.
High or low frictional coefficient.
Resistance to abrasion or wear.
Effects resulting from work done upon the material.
Effects resulting from relation of superficial area to volume.

*General Motors Company, Detroit.

Most of these factors have a direct bearing on the strength. Before discussing the effect of these factors, however, let us consider for a moment the definition of strength and the means by which we determine same.

Strength Defined: There are three simple kinds or conditions of strength and three others more complex, as follows:

(a) Tensile strength—resistance to rupture or tearing apart.
(b) Compressive strength—resistance to collapse or crowding together.
(c) Shear strength—resistance of adjacent integral parts to sliding past one another.
(d) Transverse strength—resistance to bending or flexure.
(e) Shock strength—resistance to failure arising from any stress suddenly applied.
(f) Endurance or fatigue strength—resistance to failure from repeated stresses of a value usually less than that of the elastic limit of the material.

Most other conditions of strength can be resolved into the first three. Indeed, it may be safely said that all these are present in any rigid body acted upon by a force. Thus, if a piece of cast iron or hard steel be subjected to compressive stress to the point of failure, it will fly into many pieces as if it were actually pulled apart by powerful tensile stresses. Again, if a piece of soft steel be pulled apart in tension, the rim of the fracture will invariably show the result of shearing action. Likewise, whenever there is shear there are also tensile and compressive stresses.

The methods by means of which these various indications of strength are determined and the manner in which the results are given may be summarized as follows:

Tensile Strength: Obtained by suitable machinery for pulling apart a cylindrical or prismatic test specimen and for weighing the force used in the pulling process. The results are expressed in pounds per square inch of cross section or similar units in the other systems.

There are three other important elements ordinarily brought out in a tensile test, i. e.:

Elastic limit.
Per cent elongation.
Per cent reduction of area.

This elastic limit is expressed in pounds per square inch and is defined as that point on the load-deformation curve, when the numerical ratio of load to deformation ceases to be constant. It is obtained by suitable instruments for measuring the rate of increase in length to increase in load. There is often considerable argument as to the elastic limit of a material because our methods of determining it are only approximate. The more refinement with which we carry out the test, the farther down the stress-strain or load-deformation curve the proportionality appears to cease, while the commercial elastic limit or yield point may be from 2,000 to 15,000 lbs. per square inch, above a reasonably accurate determination of the proportionality limit.

The elongation is variously considered as a measure of the toughness, the hardness and the ductility of the material. As a matter of fact, it is only a very rough approximation of either of these qualities. It does, however, give us some idea of how much energy the material will absorb before failure. If the point of fracture occurs outside the middle third or if the

ratio of gauge length to diameter is different from 4, the elongation thus obtained is not comparable to the elongation of a standard 2″ g.l., .505 diameter test specimen.

The per cent reduction of area shows very much the same things that the elongation does, though it is supposed to be a measure of the malleability rather than the ductility. Both the elongation and the reduction of area, with all their limitations, are regarded as the best indications we have on the general reliability of the material.

Compressive Strength: We run into difficulties in making compression tests that are absent in the tensile test. First, if the specimen is long as compared to its cross section, we are apt to get sideways bending instead of true compression. Second, we are running counter to nature in that we are trying to force two particles to occupy space previously occupied by only one. This effect is cumulative as the test progresses.

We can, however, determine the elastic limit in compression and by carrying the tests further we can determine whether the material is brittle or malleable. The test is valuable because there are many materials which will support tremendous loads in compression, but have practically no tensile strength; as, for instance, liquids (in a closed container), stone, brick, concrete and, to a lesser extent, cast iron.

Shear Strength: The shear test is not very often resorted to. First, because of the difficulties and expense of making proper fixtures and of securing a correct value not affected by the bearing values and side thrust forces. Second, because the simpler tensile test gives a reasonably correct means of estimating the shearing strength. A torsion test subjects the material to shearing stress and is sometimes used in place of a shear test. The results of both the shear and compression tests are expressed in pounds per square inch of surface acted upon.

Transverse Strength: The test for transverse strength is quite valuable as it often similates the actual conditions of loading. The transverse test specimen is usually in the form of a beam of uniform section, supported at the ends or cantilever fashion at only one end. The loading is always such as to cause a maximum longitudinal stress at the top and bottom of the beam, with proportional values in between. Whether the stress will be tension at the top and compression on the bottom or vice versa, will depend upon the method of loading. The beam is also subjected to shear both transverse and longitudinal. The failure is almost always caused by the tensile stress, though occasionally a wooden beam will fail in longitudinal shear and a reinforced concrete beam in compression. The results are expressed usually in terms of the tension in the extreme fibres at the elastic limit and at failure. The stress is computed from the formula:

$$\text{Fibre Stress} = \frac{\text{Bending Moment}}{\text{Section Modulus}}$$

The formula holds true only up to the elastic limit of the material, but is used to compute a figure which represents the maximum strength and is called the "Modulus of rupture."

Shock Strength: Which is the antithesis of brittleness, is measured in many ways. There are at least six different machines which are used more or less for this purpose. None of them is quite satisfactory. The stresses caused by these machines are very complex combinations of tension or compression and shear. The velocity of impact is made a fixed quantity when we are certain that different impact velocities have different

effects on materials. The test specimen is usually made with a nick or groove on the tension side, which must needs give complicated stresses incapable of being resolved into simple units. The better way would be to make an impact tensile test on a cylindrical or prismatic test piece, with varying striking velocities and sufficient energy to cause failure on the first blow. Then plot the results thus obtained in foot-pounds of energy per square inch, against velocity of impact.

For other types of material, we may use a transverse impact bending test similar to the Charpy, but without the notch in the bar. Or perhaps we could obtain better results using a drop hammer, increasing the height of fall of the tup by small increments for each blow. The impact strength of brittle materials could be determined in this manner. While the elastic limit or point of permanent set would be the only element obtainable in ductile materials.

Fatigue Strength: The fatigue strength or endurance is fast being recognized as an important quality or property in the construction of machines and articles of every description, the designer never aims to load the material to any point above or even near the elastic limit. But even though the maximum load may be far below the elastic limit, if this stress varies over a considerable range, ultimate failure may result from the repeated stresses. Thus the live axle shaft of a semi-floating automobile axle is subject to a change in stress for every half revolution of the wheel, from a compressive fibre stress of a possible 20,000 pounds per square inch to a tensile stress of a possible 20,000 pounds per square inch, a total variation in stress of 40,000 pounds per square inch twice in a revolution. Failures frequently do occur from this cause.

There are half a dozen machines on the market for determining the fatigue strength, all of them repeating the stress in cycles at a more or less constant speed. The results are expressed in the number of cycles before failure, with a statement as to the stress and the cycle per minute. Another way to do is to determine the stress required to cause failure, in say a million repetitions at various speeds.

Most of the machines used at present for this purpose, test a very restricted section of the specimen, which means erratic results, due to the small volume of metal tested and the stress whorls. The writer is using a machine which gives a constant stress over a test specimen the same size as the standard 2″ tensile test piece.

Cost: Returning now to the properties of materials, let us discuss these points and see how they affect the strength or limit its use. In general, the cost depends upon three things, i. e., ratio of amount desired to quantity obtainable, extent of its usefulness, and, third, the work required to get it into the finished shape. We are, however, in this paper, concerned more with the factors bearing directly on the engineering features and cannot dwell on cost analysis here.

Weight: Heaviness is a quality which is desirable only in a comparatively few instances and then only as a means to some other end. For instance, weight is necessary on the drive wheels of a locomotive, automobile or tractor, merely because a portion of this weight is resolved into a force which causes forward motion in the vehicle. Again weight is desired in the rim of a flywheel to cut down the accelerations caused by inequalities in the torque. Again, heaviness is useful in increasing stability of structure when subjected to wind pressure or to vibration from any source.

In general, heaviness is an enemy to the engineer and many times 90%

of the total amount of material he uses merely supports its own weight. Lightness is a thing to be attained by all means and we are justified in spending any amount of money to develop a material which will have at once, the strength of steel and the lightness of wood. (The light automobile in which the material has been utilized to the very best advantage uses two pounds of material for every pound of live load it carries). Not infrequently 30 pounds of material are required to carry one pound of live load.

It is very difficult to arrive at a proper conception of the connection between weight and strength, since the former varies with three dimensions, while the latter varies in general with only two for a given material. The best approximation we can devise is when we assume a constant X-section and express the strength in terms of the third dimension, which is directly proportional to the weight. Imagine a prismatic bar supported at its end and extended to such a depth or height that its weight would be sufficient to cause fracture in the bar. Then

$$\text{Length in ft.} = \frac{\text{Tensile Strength}}{12 \times \text{wt. per cu. in.}}$$

Some examples of this comparison of weight to strength are given below for typical materials. The figures given are average values and indicate the length of a bar set vertically, which will be just sufficient to cause failure. I shall call this figure the strength per unit of weight:

Material.	Length to cause failure by dead weight. Tension.	Compression.
Oak with grain	35,700 feet	20,800 feet
Oak across grain	5,900 "	5,900 "
Yellow pine, with grain	43,500 "	25,400 "
Yellow pine, across grain	2,200 "	5,100 "
Soft wood, with grain	35,700 "	20,800 "
Soft wood, across grain	5,900 "	5,900 "
Manila Rope	20,600 "	..... "
Limestone	35 "	8,818 "
Granite	694 "	17,350 "
1:2:4 Concrete	178 "	3,000 "
Cast Iron	6,400 "	32,000 "
Common Steel	15,000 "	30,000 "
High Grade Alloy Steel	59,000 "	88,000 "
Copper, hard drawn	13,100 "	18,400 "
Aluminum, No. 12 alloy	15,200 "	20,000 "
Duraluminum	28,000 "	40,000 "

From this it is seen that steel is far and away the material having the greatest inherent strength. Wood has excellent inherent strength parallel to the grain, but is woefully lacking in the direction at right angles to it. Aluminum is as strong as common steel, weight for weight, but lacks the ductility and uniformity of the latter.

Workability or Machinability: Next to cost this property is the most important. While its bearing on the strength is quite indirect, it is of such considerable importance that careful consideration should be given. Aside from cost, the greatest advantage of wood over stone or metals is the readiness with which it can be cut and shaped. Likewise the great advantage of concrete is in its adaptability to being poured into shape, as

compared to the slow and tedious methods of working stone, even though the latter has so very much greater strength.

This property of machinability of metals is of vast importance to the manufacturer and user of machines and it is a problem which causes more arguments back and forth between the machinists, engineer and heat treat experts than any other. The writer cannot emphasize too strongly the necessity for our getting straight on this problem, developing standards which will enable us to grade the degree of machinability of every material. It isn't always the hardest steel which is the most difficult to machine either. Frequently the soft, stringy steel gives more trouble than a considerably harder material.

Toughness: In general, toughness is the antithesis of machinability. The steel containing 12% of manganese used for frog points and parts subject to great wear, is quite soft and has relatively mediocre tensile strength, but it is one of the toughest materials known. Alloy steels and manganese bronze have this property to a marked degree.

Hardness: A great deal of work has been done in recent years to establish the degree of hardness of a material and to harmonize this property with that of toughness, machinability and tensile strength. The three best known methods of determining the hardness are the scratch method, using a scale of 10 minerals for roughwork, or for finer work a diamond point requiring a certain pressure to produce a scratch of a certain size; second, the Brinell ball impression method, and finally the sclerescope or bounce method. Owing to the refinement necessary in the scratch method, the latter two methods have gained the greatest prominence. In general the following rules hold for a given material:

(a) Tensile strength increases with hardness to a point where the internal stresses become large, after which it diminishes.

(b) Shock strength decreases with increasing hardness.

(c) Shear and compressive strengths increase with increasing hardness.

Uniformity of Structure: We are badly handicapped in the materials we are compelled to use, in that we have no light material with a uniform structure. All of the readily workable woods, as has already been shown, have a strength in one direction 6 to 20 times that of the other. Our clays and stones are all made up of more or less large heterogeneous particles cemented together rather poorly. It is only in our metals that we approach anything like uniformity of structure and even here we attain only uniformity in a restricted degree. If we could make steel, aluminum or bronze having the solution-like uniformity of glass without its brittleness, we should be at the beginning of a new era in materials.

Resistance to Chemical Action: None of the ordinary materials are strongly resistant to chemical action. The two most common forms of weakness resulting from chemical action are by oxidation or by the dissolving action of acids or alkilis. We find it necessary to form some protective coating of a less active material, as for instance oil, paint, another metal or by a coating of oxide itself, as in the case with aluminum. The action progresses very much more rapidly when there is a combination of the two processes. Thus, where steel is alternately wet by water containing small amounts of acid and then subjected to the action of the oxygen in the air, the destruction is very rapid.

Electrolysis: This is similar in its effect to chemical action. It is not as frequently found destroying materials as chemical action and requires

certain peculiar conditions as an electric current caused by dissimilar metals in a liquid solution, but it occasionally causes considerable trouble. The writer recalls the bottom of a ship made up of a very expensive sheet metal, which was destroyed in a few weeks by the electrolytic action between the monel metal sheet and the steel frames.

Temperature Effects: The effect of high or low temperatures is one of vast importance. For construction purposes we are interested in the strength of materials at temperatures from 40°F below zero to 150°F above zero, but for special purposes we are desirous of using certain materials up to 4,000°F, which is 30 times the range between our winter and summer. None of the materials of vegetable or animal origin can be used in temperatures very much above the boiling point of water, as the water in evaporating breaks down some of the cells and in addition to the valuable resins, saps, tar, etc., which aid in the cohesion of the material, are driven off.

The heavy bearing metals fail almost as quickly as the fibrous materials, though occasionally good up to 600° F.

The ferrous metals have an increase in strength and ductility for several hundred degrees and then have a sharp decrease until at a red heat (1,100° F), it is less than 10% of its strength at ordinary temperatures. At 2,500°F all of our construction metals have reached the liquid condition.

We are limited, therefore, in our explorations of higher temperatures, to the use of a very few refractory oxides and rare metals. It is needless to say at a convention of heat treaters and metallurgists that certain beneficial or detrimental results are obtained in steel and to a lesser extent in other metals, by the manipulation of temperatures.

Another thing to be considered when developing metals, is that low temperatures, even the drop of only a few degrees below freezing of water, increases the brittleness to a surprising extent. Very little has been done in determining the shock strength of various materials at various temperatures. It is a very promising field for research.

Resistance to Moisture: All of the materials having a cellular structure like wood, or a porous structure like most forms of clay and stones, are very seriously weakened by the presence of moisture, though it is more often that a change of the moisture into solid or gaseous phase is the direct cause of the damage. Moisture in cellular materials will cause swelling and distortion of varying degrees, but has no effect on metals except as an aid to chemical action or electrolysis.

Resistance to Animal Life: Here again the materials having a cellular structure are subject to deterioration through bacteria or insects, while metals and inorganic materials are immune from their attacks. The remedy is through the impregnation of the cells with something in the nature of creosote, zinc chloride or an inorganic salt.

Friction Coefficient: The value of the frictional coefficient is a very important property when we have rolling or sliding contact between two materials. In some cases we desire a high coefficient as between locomotive wheels and the rails, an automobile drive wheel and the ground, or between brake shoes and the brake drum. More frequently, however, we desire a minimum which is obtained only by means of an oil film. The maintaining of this oil film under all conditions is the greatest problem in securing a bearing of low friction, though the character of the two surfaces is also important.

Usually dissimilar materials operate together better than if the rubbing

surfaces are of the same material. Besides the oil film, attempts are now being made with more or less success to the introduction of a solid lubricating film between two surfaces. The only successful material so far discovered for this purpose is flake graphite.

In the absence of an oil film we are limited in the use of metals for bearing surfaces by reason of the wear or abrasion of one upon the other and second, by the "seizing" or welding action. The wearing action is overcome only by the increasing size of the surfaces, thus decreasing the unit bearing pressure, while the "seizing" action is minimized by the use of a hard service on one side and a soft one on the other. For instance, we have steel on babbitt or bronze; steel or brass on wood or babbitt; hard steel on soft steel, or, better still, cast iron; or the extremely hard jewel surfaces on hard steel.

Effects of Work: The effects of which we are speaking is meant that upon the structure of the material. On wood or natural stone very little can be accomplished. Brick can be made much harder and denser by pressure, but it is only on the metals that the structure can be thoroughly affected by work. Even among the metals we are limited in the extent we can work it—cast iron for instance, cannot be worked. There are two ways in which we can work a metal—hot or cold. The former is usually known as forging or hot rolling and is applied to steel with remarkably beneficial results. The structure is refined and strength and ductility increased to a remarkable degree. Hot working is applied to the copper alloys to a limited extent and very little to other materials.

Cold work can be applied to any of the metals and has a very beneficial effect in making the material more dense, raising the elastic limit (usually at the expense of the ductility, though not always) and to a lesser extent increasing the tensile strength.

Cubes Versus Squares: The effect of the relationship between the superficial area and the volume has been all too little considered. The volume varies with the cube of a given dimension while the area varies as the square. Among the various functions imported to the metallurgist and designer are the following:

(a) Mass or weight is proportional to the *cube* while strength is proportional to the square.

(b) Heat capacity is proportional to the cube while radiating surface is proportional to the square.

(c) Absorption of heat is proportional to the square while capacity is proportional to the cube.

(d) The surface presented for dissolving varies as the square, while the amount to be dissolved varies directly as the cube.

These laws work out in such a manner that if part is made up of a thick or a thin section there is apt to be a wide variation of temperatures between the two sections in either heating or cooling. The result is that two sections attempt to expand or contract at different rates, with disastrous results.

The only way to avoid these internal stresses is to maintain as far as possible, a uniform ratio of superficial area to volume for every section of the particular design.

Conclusion: Just a word in conclusion about the "ideal" material.

First, it must have great strength in all directions in proportion to its weight, which means it must be crystalline or amorphous instead of fibrous or cellular. Second, it must be resistant to heat up to at least 700° F,

which means an inorganic substance and it must become liquid or at least soft under heat, which means it will likely be a metal. Third, it must be workable or machinable at room temperatures. Fourth, it must be plentiful. Finally, it should have a low coefficient of expansion. The nearest guess that the writer can make as to what this "ideal" material will be is that one of the constituents is to be aluminum, magnesium, calcium or lithium held in an alloy or a solid solution by means of an unknown substance.

NOTICE

Change of Headquarters

Beginning November 20th, 1920, address all correspondence to

American Society *for* Steel Treating

4600 Prospect Avenue
CLEVELAND, OHIO

NEW DEPARTMENT AT THE UNIVERSITY OF MICHIGAN

Lieutenant-Colonel A. E. White, President of the American Society for Steel Treating has been promoted from the Department of Chemical Engineering to be Head of the new Department of Engineering Research at Michigan University.

The announcement is as follows:

Aiming to place the University of Michigan in close and intimate contact with the industries of the state so that it may serve them in the most practicable way possible, the Department of Engineering Research has been established and $10,000 appropriated by the Regents for its development.

This department has been inaugurated for the use of the manufacturing concerns of the state to promote investigation and improvement in them, and to aid in all advancement of their welfare. It will be the scientific investigation laboratory for all the industries of the state.

Due to unprecedented industrial development in Michigan this state has risen during the past 10 years from 13th place industrially to 7th place among the states, and its yearly production is many times as great as at that time. The Michigan Agricultural College, devoted largely to the interests of better farming, has been a state institution for a part of the producing organs of the state which produced annually only about $500,000,000 worth of commodities. Up to this time the industries, the producers of wealth evaluated at more than $2,000,000,000 annually, have been left entirely to their own resources, a condition of affairs which will now be rectified by the Department of Engineering Research.

The Regents have appointed Prof. A. E. White of the department of chemical engineering as director of the new department. Professor White has been actively engaged in the bringing about of the laboratory idea and has had wide experience in the line with which the department is to deal. For several years, director of the investigation laboratory of one of the largest manufacturing concerns in the country, he came to the University in 1911 to assume a position as instructor and in 1913 was made assistant professor. Leaving Michigan in 1917, Professor White entered the army with the rank of captain in the Ordnance department, where he had full charge of the metallurgical inspection of all ordnance material.

Rising soon to a major, he left the army in the spring of 1919 with the rank of lieutenant-colonel, when he returned to the University where he was then given the title of full professor. Professor White has recently been elected president of the American Society for Steel Treating, a newly formed organization.

The movement for the installation of a department such as has been effected was started by the Chicago alumni in 1916, but owing to the unsettled conditions of the time, no effective consideration was given the matter until it was brought to the attention of the Regents by the Manufacturers' Association last year. The advisability of establishing the department has been in the hands of a committee consisting of the President, Regents Hanchett, Clements, and Leland. Dean Cooley, and Professors A. E. White and J. C. Emshwiler. This committee has worked with a committee from the Michigan Manufacturers' Association, consisting of M. W. Neal, H. C. Bulkley and F. S. Bigler.

Developing the idea from its inception, these committees have carried it to its present state, and at the last Regents' meeting $10,000 was

appropriated to start the work. Officials regret that more could not be obtained, but present demands upon the University funds are so great that it was found impossible.

Personnel Includes 100 Men

The personnel of the advisory committee appointed to supervise the operations of the department consists of 100 prominent business men about the state, appointed with reference to location and the variety of interests they represent. An executive committee of 17 has been elected by the larger committee and there is also an administrative committee consisting of the dean and heads of professional departments in the engineering college, and the director of the new department.

Speaking of the functions of the new department, Professor White said, "It must be appreciated that this is a state university, and therefore the results of the work done in it must be considered common property. We believe that much valuable work may be done by means of the new department for individual concerns and groups of associations. We do not expect that we will engage in routine work, for that can be done to much better advantage by the various industries.

"It is expected that concerns having work done will pay for the actual cost of the work. The University is very glad to place at the disposal of the manufacturers its library facilities and as much laboratory facilities as can be done without undue interference with teaching. It is believed that this will react most beneficially to the industries and also will aid the University in some small part, as the faculty will thus have an opportunity to keep fully up to date in all problems of industry through the advisory and investigatory work which they will take part in.

"Already, unsolicited, and before the official establishment of the department, many requests for service have come in. They include headlight investigation, requested by prominent motor corporation, research work in the field of a new and cheaper motor fuel, request for help in problems raised by corrosion in the valves and fittings produced by one of the producers in that field, and information on the properties and characteristics of seamless steel belting and many others of similar nature."

The New Standing Committees

At a meeting of the Board of Directors held in Cleveland, October 9th, the following Committees were appointed:

Finance Committee

Mr. W. S. Bidle, Pres., W. S. Bidle Co., Cleveland, Ohio, Chairman, one year.

Mr. J.H. Herron, 2041 E. Third St., Cleveland, Ohio, two years.

Mr. C. M. Campbell, Supt., Pioneer Alloy Products Co., 16601 Euclid Ave., Cleveland, three years.

Publication Committee

Prof. H. M. Boylston, Case School of Applied Science, Cleveland, Ohio, Chairman, one year.

Mr. E. E. Thum, Assoc. Editor, Chemical and Metallurgical Engineering, 10th Ave. at 36th St., N. Y. City, two years.

Mr. J. V. Emmons, Cleveland Twist Drill Co., Cleveland, Ohio, three years.

Meetings and Papers Committee

Mr. H. J. Stagg, Asst. Mgr., Halcomb Steel Co., Syracuse, N. Y., Chairman, one year.

Mr. Geo O. Desautels, Vice Pres., Imperial Drop Forge Co., Indianapolis, Ind., two years.
Mr. Victor Hillman, Metallurgist Compton Knowles, Worcester, Mass., three years.

Library Committee

Mr. J. C. Hartzell, Blue Ash, Ohio, Chairman, one year.
Mr. Z. Jeffries, Aluminum Co. of America, Cleveland, Ohio, three years.

Standards Committee

Mr. T. D. Lynch, Westinghouse Electric and Mfg. Co., Pittsburgh, Pa., Chairman, one year.
Mr. H. L. Green, Willys-Overland Co., Toledo, Ohio, two years.
Mr. P. H. Gilligan, Souther Engineering Co., Hartford, Conn., three years.

Research Committee

Prof. Fred Crabtree, Carnegie Institute of Technology, Pittsburgh, Pa., Chairman, one year.
Mr. H. J. French, Bureau of Standards, Washington, D. C., two years.
Mr. C. N. Dawe, Studebaker Corporation, Detroit, Michigan, three years.

Constitution and By-laws Committee

Capt. C. D. McQuigg, Electro-Metallurgical Co., Niagara Falls, N. Y., Chairman, one year.
Mr. J. E. Halbing, Asst. Supt., Heat Treating, Ingersoll-Rand Co., Phillipsburg, N. J., two years.
Mr. J. C. Morrow, Steel Company of Canada, Hamilton, Ont.

Nominating Committee

Mr. J. F. Harper, Asst. Supt. Forge Shop, Allis-Chalmers Co., Milwaukee, Wis., Chairman, one year.
Mr. H. G. Kiefer, Studebaker Corporation, Detroit, Michigan, one year.
Mr. A. E. Bellis, Springfield Armory, Springfield, Mass., one year.
Mr. A. W. F. Green, Chief of Laboratory, John Illingworth Steel Co., Philadelphia Pa., one year.
Mr. C. U. Scott, care C. U. Scott and Son, Rock Island, Ill., one year.

Membership Committee

Mr. T. E. Barker, 1953 Hastings St., Chicago, Ill., Chairman, one year.
Mr. J. F. Harper, Asst. Supt., Forge Shop, Allis-Chalmers Co., Milwaukee, Wis., two years.
Mr. P. A. Lovegren, Asst. Supt., Standard Forgings Co., Indiana Harbor, Ind., 3 years.

NEW CHAPTER IN SYRACUSE

The first Chapter to be established since the Amalgamation was completed, occurred at Syracuse on the 19th of October. The honor of being the first Chapter was justly deserved by that industrious manufacturing center, as later developments proved.

The preliminary organization meeting was held at the Chamber of Commerce, and was attended by 23 representatives of the leading industries of the city. Here the plans of action were decided upon, and the date of the first meeting determined.

Invitations were sent out to those interested, to meet in the Assembly room of the Chamber of Commerce on Tuesday evening, October 17th. In response to this invitation 175 were present, making necessary the use of an additional room for the meeting and even then many had to stand.

The meeting was addressed by the National Secretary, Mr. W. H. Eisenman and by a number of local men.

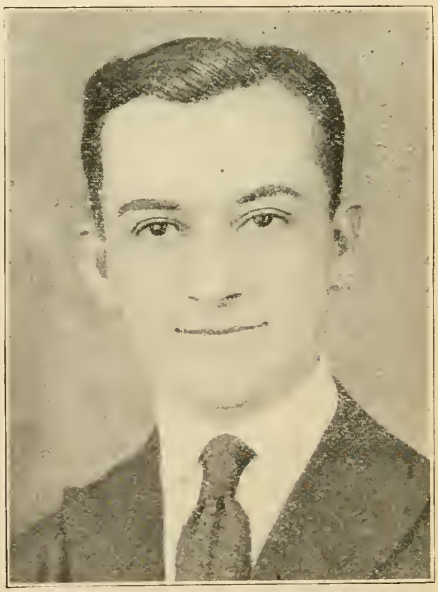
A very lively discussion of points of interest in heat treating was opened up and showed the broad scope and wonderful possibilities of future meetings.

Syracuse, as the Baby Chapter of the Society, established a new record by having 76 applications for membership presented at the opening meeting. The record was formerly held by the Lehigh Valley Chapter with a total of 75 applications.

Syracuse Chapter, with its corp of efficient officers and committeemen, is welcomed by all the other Chapters and the National Board of Directors, with full assurance that the work so auspiciously commenced, will be continued.

The officers selected were as follows: Mr. Howard J. Stagg, Jr., Assistant Manager of the Halcomb Steel Company was elected Chairman; Mr. Frederick C. Raab, Metallurgical Engineer of the Brown-Lipe Chapin, as Vice-Chairman and Mr. William F. McNally, of the Willys Corporation, New Process Gear Division, as Secretary-Treasurer. The following were elected as members of the Executive Committee: Mr. L. M. Fenner, Chief Chemist and Metallurgist, H. H. Franklin Mfg. Co. Mr. R. C. Gebert, Chief Metallurgist, The Hammond Steel Company, Inc. Mr. P. A. Hopkins, Engineer, Penn Spring Works. Mr. E. D. Newkirk, Metallurgist, Onondaga Steel Co., Inc., and Mr. O. L. Van Valkensburg, Chief Chemist, Crucible Steel Company, Sanderson Works.

H. J. STAGG,
Chairman Syracuse Chapter



HARRY BLUMBERG,
Secy.-Treas. Chicago Chapter

CHAPTER NEWS

The Buffalo Chapter of the American Society for Steel Treating held their regular monthly meeting at the University Club on Monday Evening, November 1st. Mr. J. V. Emmons Chief Chemist and Metallurgist of the Cleveland Twist Drill Company gave a very interesting talk on "Tool Hardening Process," which was illustrated with lantern slides.

LESSONS LEARNED IN THE MANUFACTURE OF MUNITIONS AND ORDNANCE THAT CAN BE APPLIED TO THE PEACE-TIME PURSUITS OF INDUSTRY.

By F. V. Larkin.*

It is the purpose of this paper to point out certain lessons, learned in the manufacture of munitions and ordnance, that can be applied to the peace-time pursuits of industry.

The conclusions on which these lessons are based were established in the period extending from 1915 to 1919, during which the author was associated in the manufacture of some three million projectiles and a half million high pressure seamless cylinders. They are drawn from the viewpoint afforded one in charge of operations, whose duty and privilege it was to deal with the production, heat treatment, and fabrication of steel, the organization and training of the men who did the work, and with the officials who administered the procurement of munitions and ordnance for the Allied Powers, and for the United States Army and Navy.

These lessions thus naturally divide themselves into two groups, those having their origin in the realm of steel, and those having their origin in the realm of human nature.

Starting from the standpoint of steel in the open hearth development will be made through the forge shop, heat-treating department, testing department, up to and including the men who did the work.

In the open hearth we found that a complete history of each open hearth heat, originated in the open hearth, and compiled by the operators themselves, went far to eliminate the darkness and semi-mystery that too often surround the production of steel — particularly the production of off heats.

Most open hearth men must necessarily get the knowledge of their jobs, first by word of mouth, and later by experience, rather than by personal study. For these reasons they become careful and accurate observers. Like most uneducated men, they have an undue aversion for writing down any specific statement, or if they cannot write, to making any definite assertion that is to be written down on their authority. Then too, such men have an undue fear of truthfully stating that they have done something wrong or, that they have made a mistake. As a consequence, they keep away from the necessity of reporting discrepancies, with the result that the quantity and quality of their operation is raised.

In the rolling mill we reached the conclusion that much of the expense of chipping ingots and blooms can be eliminated by a reasonable care in the preparation of moulds and rolling. In substantiation of this, it may be of interest to know, that the company whose operation is being cited, never chipped one single billet of steel for over three million projectiles, and that their former practice of chipping ingots made for cylinder plates was abandoned.

As to the forge shop, a pyrometer in the forge shop pays.

In spite of the dire predictions of the superintendent of the forge department a radiation pyrometer was installed in the projectile forge shop. This revealed, as had been assumed it would, too wide a range of forging temperature. Uniformity of heating followed, and with it two wholly unlooked-for beneficial results, namely, a decrease in the number of forging tools required, and a decrease in the number of defective and eccentric forg-

*Head Department Mechanical Engineering, Lehigh University, So. Bethlehem, Pa.

ings. This pyrometer was mounted on a piece of pipe bent in the form of an L and hinged so that it was normally held up and out of the way by a counterweight. As the forgings were placed open end up in an inspection pot, the pipe carrying the pyrometer could be drawn down so that the bottom of the cavity was always exposed a uniform distance from the pyrometer end.

In the heat-treating department it was found that furnacemen should be taught enough of the operation and use of the pyrometer to enable them to look upon it as an aid to their work rather than as a tell-tale of their operation.

A recording pyrometer was installed near the drawing end of a long continuous coal-fired annealing furnace. The furnace was used for drawing quenched steel to a carefully predetermined temperature and was normally so fired that the steel was slowly heated at first, reaching its maximum temperature under the pyrometer. The fireman was duly impressed with the necessity of producing a uniform curve on the chart in the superintendent's office. Soon it was discovered that all the steel was coming uniformly soft. Early investigation showed that the correct drawing temperature had been prescribed and that the fireman had maintained his fires so as to produce a perfect chart. Then followed a checking of the pyrometer, a checking of chemical analysis, a review of the history of the heat and its progress through the plant up to the furnace again. Here further investigation showed that the fireman had learned that by firing the charging end heavily he could best produce a uniform curve on the pyrometer chart. The result was that the steel was overheated shortly after charging, then cooled down to the proper temperature when it passed the pyrometer, and drawn out of the furnace looking normal.

We also found that time is a vital factor in the heat treatment of steel.

In order to maintain constant the temperature of the steel, the quenching medium, and the cooling water, it was found well to synchronize the operations of charging, drawing and quenching with a gong which indicated the desired interval. Annealing furnaces happened to be so arranged that they could also be governed by the same gong. Under normal conditions the operation was as follows: On the stroke of the gong, the piece in the quenching bath was withdrawn and charged into the annealing furnace, a piece was drawn from the quenching furnace and placed in the quenching bath, and a corresponding charge of the hot furnace and discharge of the annealing furnace made.

The result was that time in heating furnace was constant, time in quenching bath was constant, time in drawing furnace was constant, pounds of steel quenched per hour was constant, all of which was conducive to uniform firing and uniform speeds for oil pump and circulating water pump. The operation went on day and night six days a week with remarkable uniformity.

In the testing room it was established that the ordinary testing machine can be adapted for hardness testing and for gauge testing in an emergency.

Our hardness testing equipment was destroyed by fire. Before it could be replaced the necessity for making hardness tests arose. A supply of steel balls of the proper size was obtained. One of these was magnetized and placed on the upper compression head, the machine reversed and the required load applied. The process was, of course, too slow for production, but apparently satisfactory.

The production of one thousand pieces per day, each of which were required to withstand a hydrostatic test to three thousand pounds per square inch, made it necessary that a supply of accurate gauges be maintained. Formerly the manufacturer of the gauges had made repairs and calibrations, but in the stress of the emergency it became impossible to get adequate service. Accordingly an oil plunger gauge-testing device was made up, so proportioned that there would be an even decimal ratio between beam reading and gauge reading. This placed in the machine, operating in compression, made it possible to produce any desired oil pressure and thereby calibrate the gauge. Arrangement was, of course, made for turning the piston of the gauge tester to eliminate friction. This device calibrated against a gauge, certified by the Bureau of Standards, showed remarkable accuracy.

This concludes the discussion of those lessons having their origin in the realm of steel. Passing now to the second group, which have their origin in the realm of human nature, development will be made under the two headings: trade secrets and specifications.

Prior to 1914 practically all our knowledge of munitions and ordnance was confined to a few companies who held an ungrudged monopoly on the production of armament and implements of warfare. Such discoveries as were made during the period of limited expansion of our Army and Navy, were carefully guarded as trade secrets, justly enough considered the property of the companies who had evolved them. So apparent was this that in 1915 a writer in one of the technical magazines made the prediction, that if the United States should become involved in the war, it would take three years to develop the necessary tools and gauges adequate to cope with the situation.

It is an apparent anomaly that from the very ranks of those thus formerly charged with the responsibility of hoarding and monopolizing the secrets of the art of the heat treatment of steel, there should spring such an organization as The American Society for Steel Treating. Particularly is this true, in view of the Society's statement, that one of its specific purposes is "to collect, publish and disseminate knowledge." Shades of Samuel Gompers! A strict adherence to the precepts of trade unionism, on the part of those engaged in educational work, would require that they look upon this attempt to disseminate knowledge, as an infringement upon the province of their profession.

But we are all coming to the conclusion that it is erroneous to hold that the bulk of our educational work is done in the schools, that it is likewise erroneous to contend that the only teachers are those whose remuneration comes from the specific task of teaching. Every industry is an institution of education, and all the leaders in it are teachers, whether they consider themselves teachers or not. The Society's entrance into the field of education is implied in their quotation from the immortal Roosevelt: "Every man owes some of his time to the upbuilding of the profession to which he belongs." Therefore this occasion for joining hands with you in an interchange of ideas is welcomed, quite as much as the opportunity it affords of greeting you as a fellow educator.

Not only were we confronted at the outset with the trade secrets referred to, but the arts of systematic shop production and inspection and the manufacture of tools and gauges were likewise beyond the realm of our experience and, therefore, to us, trade secrets. We attacked these vari-

ous handicaps from a pedagogical standpoint, which in the last analysis holds that secrets are relative things. That is to say, what is a secret to one man is an axiom to another. So we made a rather daring classification and placed secrets in the same category with ghost mysteries, ouija boards, superstition and ignorance. Then we laid down and defended the maxim that the other fellow's secret was of less value to him than our ability and determination to unravel it were to us. We soon realized that, knowing the fundamental principles which serve as a foundation for any secret or process, we had only to bring into operation a sufficient amount of logically directed and persistently applied energy and ability, to duplicate or outstrip the achievements of our competitors.

The manner in which our leaders and workmen responded to teaching was so splendid and so satisfactory that we found a lack of experience was a handicap of much less consequence than a lack of spirit. The conclusion established in regard to trade secrets follows: If the spirit of your organization is right you can make every trade secret bearing upon your work, an incentive rather than an impediment.

In regard to specifications, it was found that the more strictly a set of fair and accurate specifications are required to be met, the better it is for the manufacturer and the men doing the work.

The preparation of specifications is an art. Particularly is this the case in specifying steel and its performance in service. No doubt many of you encountered crude, cumbersome, arbitrary specifications, prepared in haste and fear, and bearing little evidence of a knowledge either of the possibilities or of the actual requirements. The overlapping and conflicting elements of such specifications must be brought into line before any production can be forthcoming. Otherwise, demoralization and stagnation result, due to the fact that the energy and ability of the organization doing the work will be applied in a negative manner designed to show why requirements cannot be met, rather than in a positive direction determined to meet them.

At this point reference is made to what may be considered a masterpiece in specification writing, and tribute is paid to Colonel B. W. Dunn, Chief Inspector, Bureau of Explosives, Interstate Commerce Commission, for the specification known as I.C.C.3A, covering shipping containers. Carefully and accurately prepared, they are of the most rigorous and exacting nature. Yet they are fair. They can be met by the manufacturer, and they insure to the customer a product which he can purchase and use with a maximum assurance of security and safety.

Success in meeting such specifications brings gratification and pride to the workmen and to their leaders, and at the same time puts the manufacturing process on a high plane, not only raising the quantity and quality of the product, but also the spirit and ability of the men. In general, the poorest grade of work which a customer will accept, is the best that a manufacturer can possibly coach his men to produce. We taught our leaders and workmen the specifications involved in their particular departments. We taught them to know when their product was right. We taught them to stop wasting time on the repair of questionable stuff. We taught them never to ask a customer or his representative if a product was good enough. Our maxim was "Know your product is right, then present it to the customer with satisfaction and pride and he can do only one thing—accept it."

So thoroughly did this work out, that our management received a most unusual complaint from one customer's representative. Complaint was

made that the Company's Inspector was rejecting work which he, the Customer's Inspector, would be willing to accept. Such, you are assured, was not the case. Rather, the Customer's Inspector was a man whose idea of inspection necessarily involved rejection. When he found little or nothing to reject, he felt that his perogatives were being usurped. For such inspectors—and they were not all such—it is sometimes wise to permit a percentage of low-grade work to be presented in order that the authority and prestige of the customer's representative may be exercised in the rejection of some of the pieces submitted.

Notwithstanding incidents of this nature, it is felt that the demonstration of the statement first made was established. The more strictly a set of fair and accurate specifications are required to be met, the better it is for the manufacturer and the man doing the work.

In conclusion, a summation of the items discussed follows:

1. A complete history of each open hearth heat, compiled by the operators themselves, pays.

2. Much of the expense of shipping ingots and blooms can be eliminated by a reasonable care in the preparation of moulds and rolling.

3. A pyrometer in the forge shop, pays.

4. Furnace men should be taught enough of the operation and use of the pyrometer to enable them to look upon it as an aid to their work rather than as a tell-tale of their operation.

5. Time is a vital factor in the heat treatment of steel. It furnishes a logical base around which to develop a heat-treating operation.

6. The ordinary testing machine can be adapted for hardness testing and for gage testing in an emergency.

7. If the spirit of your organization is right you can make every trade secret bearing upon your work an incentive rather than an impediment.

8. The more strictly a set of fair and accurate specifications are required to be met, the better it is for the manufacturer and for the men doing the work.

9. Finally, in the equipment of any individual, personality is of more importance than technique. That is to say, unless the individual professing a knowledge of the art of steel making, has the ability to set it forth in terms simple enough to inspire a belief in him, if not an understanding of his dogma, he will not be able to materially increase either the quantity or the quality of the output of a plant.

DISCUSSION OF MR. LARKIN'S PAPER

MR. HILLMAN: I wish to state that since starting operation of our plant, our open hearth plant man makes a complete report on each person, and in going over that report personally from time to time he has increased the efficiency of our product now about thirty per cent from what it was when the plant was first started about two years ago. It is not only an incentive to him, but also an incentive to the men who work under him, and it has proven very much of a success and has given us a prestige among other plants. Other plant representatives and persons who have had occasion to visit our plant and look over our product have sort of "sat up and took notice," so to speak.

THE RELATION OF THE STEEL SALESMEN TO THE DEVELOPMENT OF HEAT TREATMENT OF STEEL

By Guy P. Bible*

(A Paper Presented at Philadelphia Convention)

It is a real pleasure to speak before this convention and have the opportunity of joining in the discussion of this work, which will mean so much to the future progress of the world.

There are some phases of heat treating which come before the salesman in most forcible, insistent, and at times embarrassing ways, and if the total accomplishment of this paper is to put before the chemists and metallurgists on one side, and the shop men on the other side, some of the difficulties we have to face, without doubt it will have done a little good.

Probably not all of you have heard the salesman's own particular, personal and best loved poem; it is brief, so that its repetition will not weary you.

He who whispers down a well,
About the things he has to sell,
Will never make as many dollars,
As he who climbs a tree and hollers.

Now the steel salesman knows a lot about wells and trees when it comes to heat treatment. He frequently hears of a customer who is in a well, only we speak of it as a hole, and he is often up a tree as to the cause of the difficulty. Unless he can help his customer up out of his particular hole, the salesman is in the hole himself. If it is characteristic of the mill people, and of sales managers to say when trouble is reported, that the fault lies, not in the steel, but in the treatment, and this is true in probably 90 per cent of all complaints, and in this fact lies the opportunity of the salesman to aid in the development of heat treatment.

The function of the steel salesman in this work, is largely that of a "thinking sponge" if such a thing were possible. He must absorb on every occasion, knowledge as to theories, methods and practice. He must apply to this knowledge the maximum reasoning power of which he is possessed, so that when occasion required, he can give out this information, in a logical, authoritative and helpful manner. He must get his information from many sources; from matallurgists, chemists, engineers, and from books and papers and lectures. But he must also get it from the blacksmith, the tool hardener, the tool maker, the machinist, the die designer, the foreman and the superintendent, and the whole line of practical men who have done so much to develop this subject, and who in the last analysis, are the fellows who translate into actual being all the prior efforts of the steel maker, chemist and metallurgist. The steel salesman then, has everything to learn, but he has something also to teach, and the man who will seriously consider this phase of his business will be the better salesman, the better man, and will make the most of his opportunity to contribute to the progress of the world.

A brief consideration is now in order of the conditions which face the steel salesman, and particularly the tool steel and the alloy steel salesman, and which he must correctly analyze and solve if he is to keep his customer, his house and his own particular self free from the many difficulties entering into the use of steels. He should by all means get full information from the user, as to the purpose for which the steel will be used, so that proper selection of grade and temper may be made. Nor is this sufficient;

*Horace T. Potts & Co.

he should know what the heat treating facilities are in the shop, and if they are bad, poor, or insufficient, he should learn whether the customer would be willing to send out to a well equipped shop, the finish machined pieces for heat treatment. Nothing is ever gained by passing over these phases of a situation, in order to make a sale, and much good may be accomplished by an intelligent consideration of them. Furthermore, if this information is given the Sales Department, or the Mill, a grade may be selected which will require much simpler treatment, which would be well within the shop capacity. It sometimes requires courage and persistance to do these things, because the salesman might be in a sense, fighting both his customer and his Sales Department, and it may be that in cases like these, the laboratory can back up the salesman and help him and themselves.

The steel salesman cannot do any original work in heat treating, but because his greatest difficulties lie in three very common human traits—Ignorance, Carelessness and Conservatism—his accomplishment, if he overcomes these characteristics, is as truly helpful as that of the leader in the profession. "They also serve who only stand and wait." His greatest opportunities lie in two special directions: the most common, getting his customer out of trouble, and the other in helping to improve methods and equipment so as to make results already good, still better.

In most cases the customer is in trouble because of one or more of the traits mentioned. We have all met the man who says, "I have been doing this for years just exactly in the same way, and never had any trouble before." Or the other fellow who says, "The 'blank' steel which I used for years never gave me a broken tool." I have been married a number of years, but I don't know that I ever envied the fellows who say, "Well, I've been married twenty years and never had a harsh word with my wife." A broken tool now and then is relished by the best of men.

The trouble may be in the manner of heating, the time for heating, the heat itself, or in the method of quenching, the quenching medium, or in the drawing. The difficulty may be further back, and lie in the forging or annealing operations which may have preceded the actual heat treatment. The steel salesman should know his business well enough, that on occasion he may suggest an analysis of each operation, or even a micrographic analysis of the various operations.

The solution of the difficulty may lie in a simple thing like changing the quenching medium from water to brine, or even in washing out the quenching tank thoroughly. Sometimes the trouble may be obviated by plugging holes with asbestos instead of fireclay, and at other times the omission of such plugs entirely may be the answer. In our organization, we are great believers in the principle of pre-heating of all tools where any considerable forging or machining has been done. We believe it is the answer to most of our questions. We also are firm believers in brine for quenching, and the removal of the tool to oil just as soon as the heat has been sufficiently quenched as to prevent any rise in temperature after entering the oil.

In all that I have said before, I have had reference largely to the heat treatment of tool steel and tools, but there is another side of the heat treatment, which of course, appeals to a great many people. I have reference to the heat treatment of low carbon steels and alloy steels. For fifty years or more we were very large importers of Swedish iron and this material entered into work where the requirements were extreme in the way of resistance to fatigue, maximum elongation, and excellent welding

and forging qualities. The war necessarily shut off this importation, and not caring to turn to another iron, we have done some little work in the way of the heat treating of soft steels and alloy steels for work where the Swedish Iron formerly went in.

In addition our business has largely been along the lines of soft steel and high grade straight carbon machinery steels, and we have taken advantage of the opportunities given to, in very many cases, suggest heat treatment and assist our customers to inaugurate and carry through, such heat treatment to success. This field offers the greatest single opportunity for a long step ahead. Every one uses straight carbon steels and iron, and every one is coming into the use of alloy steels to some extent. The steel salesman by a study of steels and heat treatment, can assist overcoming most of the failures in service which are due to insufficient strength. Too much stress cannot be laid upon this side of the work of the steel salesman in relation to the development of the heat treatment of steel.

There is another phase of this subject on which I would like to speak briefly. The most enlightened self interest, if we do not wish to place it on a higher plane, would surely call for every effort to help the steel user. It is not enough at times to overcome these common and more or less elemental troubles in heat treatment. The cause for trouble may be more fundamental, and lie in poor equipment, insufficient appliances, and lack of knowledge as to the particular type of equipment necessary to correct the difficulties, or as so often is the case to meet new conditions due to expansion in production. The steel salesman can, especially if he has the confidence of the user, do a great deal in increasing interest in new furnaces, improve tanks, pyrometers, hardness testing instruments and the whole line of what might be considered more as laboratory equipment. It is true that the steel salesman is not, for instance a furnace salesman, but if for example a man is attempting to heat a long die in a furnace which will not even take it in, which condition we have all met at times, he is surely justified in saying something which will help to correct the evil.

If I may summarize in conclusion, I might say that the function of the steel salesman is to absorb all information obtainable, gladly and intelligently; to ponder over and digest this information with judgment and reason; and to in turn give it out, freely but modestly, with the one desire to help the other fellow in his little problems, realizing that after all the measure of a man's success is the assistance he has been able to give to his fellow men. The modern proverb, clothed in the language of the day has a lot of truth in it:

> Remember my son, that when the One Great Scorer comes to mark up, He sets down, not that you won or lost, but how you played the game.

THE EFFICIENCY OF VARIOUS QUENCHING MEDIUMS AND THEIR APPLICATION

Victor E. Hillman*

(A Paper Presented at Philadelphia Convention)

Hundreds of different quenching baths have been used in the past. Moreover, letters patent have been granted for fluids that are supposed to possess remarkable properties as quenching mediums. Regardless of the infinite variety of nostrums introduced, none of them has found a place in commercial use. On the other hand, however, the quenching baths which have found extensive application in the heat treating department are: Brine, water and oil. Each has its merits. Brine imparts the maximum hardness obtainable although its drastic action may cause the steel to crack if design and mass are not taken into consideration.

Water is an excellent quenching medium, but it should be used with discretion. Thin pieces of steel should not be quenched in water due to excessive distortion and their liability to crack. The writer has been unable to draw a sharp line of demarcation between water hardening and oil hardening steels, but the results of numerous investigations indicate that high carbon (1.10) low manganese (.25) steel may be classified as water hardening while high carbon (.90) in conjunction with a higher manganese (.65) will come under the category of an oil hardening steel. Experience has proven that if the high manganese steel is quenched in water the tool will invariably crack.

It is indeed surprising that water should show its maximum hardening power at 100° F.—See curve. This same result has been confirmed by several investigators. Furthermore, water between 180° F. and 200° F. shows a hardening power nearly equivalent to oil at 70° F., 150° F. and 250° F. Consequently, the results of this research would indicate that hot water could find more extended use as a quenching medium.

On the other hand, however, water lacks hardening uniformity. Its action is erratic, inasmuch as a change of 50° or 100° F. will alter the physical properties of the hardened steel.

It is the custom in some heat treating departments to use a water bath covered with a few inches of oil for quenching purposes. The oil layer prevents hardening cracks and mitigates the shock which is incident to quenching in water direct. Tools hardened in the aforementioned manner possess practically the same hardness as that obtained from water alone. Inasmuch as the quenching mediums cannot be circulated, this method of procedure lacks practicability for large plants.

The proper selection of a quenching oil is a prerequisite for successful results in the heat treating department. The following indices are excellent criteria of the adaptability of a quenching oil:

A—Hardening Efficiency.
B—Hardening Uniformity.
C—Viscosity.
D—Flash Point.

Hardening Efficiency

The hardening efficiency of a quenching medium is ascertained by an arbitrary method. The outline of procedure consists essentially in quenching a piece of steel of standard size and analysis in a standard

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volume of oil at different standard temperatures. The hardened Specimens are Brinelled and the value thus obtained is an index to the hardening efficiency of the quenching medium at the indicated temperature.

Some idea of the relative hardening efficiency of various oils can be obtained by comparing the several Brinell values obtained at some specific quenching temperature. By following the ordinate 70 in the subjoined graphs, it will be readily seen that the compounded oil possesses the maximum hardening power inasmuch as its Brinell value is 430, as against 390, 400, 360, 380, 380 and 400, for Fish Oil, Linseed oil, Cottonseed oil, Salmon oil, Lard oil and Whale oil respectively.

The hardening efficiency of the various oils can be obtained thru a range of 40° F. to 300° F. by referring to the curves.

Hardening Uniformity

It is quite essential that a quenching fluid should possess an appreciable range in which it will harden a piece of steel uniformly. The hardening uniformity is expressed by a set of graphs which have been plotted by using the temperature of the quenching bath as abscissa and Brinell values as ordinates.

The hardening uniformity can be ascertained by noting the tendency of the curve to remain in a horizontal position. The compounded oil and the mineral oil show very good hardening uniformity. As a general proposition, the various oils show practically a constant hardening uniformity—that is, the temperature of the quenching bath may vary considerably without appreciably affecting the final results.

Viscosity

Viscosity is the degree of fluidity which an oil possesses. Temperature is an important factor in the determination of viscosity. The temperature range, given in the sub-joined data, covers the minimum, intermediate and maximum temperatures which are likely to be encountered in quenching practice. Low viscosity determines the ease with which an oil can be handled. The hardening effect of a bath varies inversely as its viscosity. Briefly, the quenching speed is retarded as the oil increases in viscosity. The figures which are given are entirely arbitrary. The viscosity value 337 for Linseed oil at 70° F. signifies that it requires 337 seconds for 60 cubic centimeters of oil to pass through a standard orifice. When the oil is heated to 150° F., 60 cubic centimeters of the oil will pass through the same opening in 96 seconds.

Viscosity—"Saybolt"

Oil	70 Deg. Fahr.	150 Deg. Fahr.	250 Deg. Fahr.
Linseed	337	96	55
Cottonseed	328	91	48
Whale	294	85	46
Fish	...	850	169
Salmon	...	786	162
Lard—No. 1	275	93	40
Compound Oil	269	69	38
Mineral Oil	500	84	36

Flash Point

The flash point of a quenching oil is the lowest temperature at which it will emit sufficient vapor to effect momentary ignition (flash) when a lighted taper is brought to within one quarter of an inch of the surface of the oil. The flash point should be sufficiently high for safety. The flash point has no bearing on the efficiency of an oil as a quenching medium.

Oil	Deg. Fahr.
Linseed	537
Cottonseed	588
Whale	481
Fish	460
Salmon	471
Lard	446
Compounded oil	383
Mineral oil	410

CONCLUSION

In the comments that follow, the various oils will be discussed under their respective classifications; namely, animal, vegetable, mineral and compounded oils.

Animal Oils

The results of this investigation show that fresh animal oils possess good hardening efficiency and a wide latitude insofar as hardening uniformity is concerned. A decade or so ago, animal oils were used quite extensively in heat treating practice. In recent years, however, animal oils have been displaced, due to a lack of uniformity in the results obtained after prolonged use. Moreover, one shipment would give results which were entirely satisfactory, while another lot of the same oil would be the source of continual complaint. Another objectionable feature to the use of animal oils was that they decomposed on continual use. Decomposition is usually accompanied by an increase in viscosity and a consequent reduction in quenching speed. Therefore, the results of the tests embodied herein must be accepted cautiously. Even though satisfactory laboratory results are obtained, the commercial value of an oil can be ascertained only by practical tests.

Vegetable Oils

The values obtained for vegetable oils parallel the results obtained from animal oils. As in the above instance too much importance should not be attached to the apparent efficiency of the vegetable quenching mediums. It should be borne in mind that they possess the property of absorbing oxygen from the atmosphere. When an oil absorbs oxygen, its refrigerating properties are impaired. Therefore, it would appear that a vegetable oil cannot be relied upon as a uniform quenching medium even though the results of the hardening tests point to the contrary.

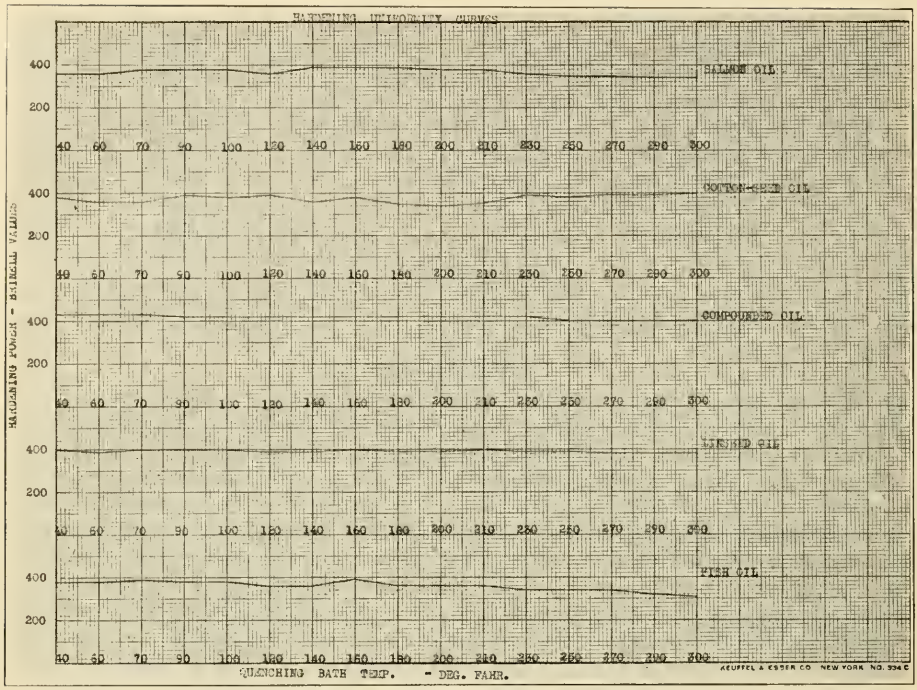
Mineral Oils

It is difficult to differentiate between the merits and demerits of a mineral quenching oil. The writer has known of cases where a mineral oil has given excellent results, but the duty imposed upon it was not severe. In other instances, mineral oils are reputed to have undergone fractional distillation to the extent that the oils would lose their fluidity and clog the pipes in the circulating system. There is a decided decrease in the efficiency of a quenching medium due to its becoming viscid. A test which was conducted some time ago showed that the tensile strength and elastic limit of test specimens decreased 13% and 14% respectively, due to the use of a thick oil as a quenching medium.

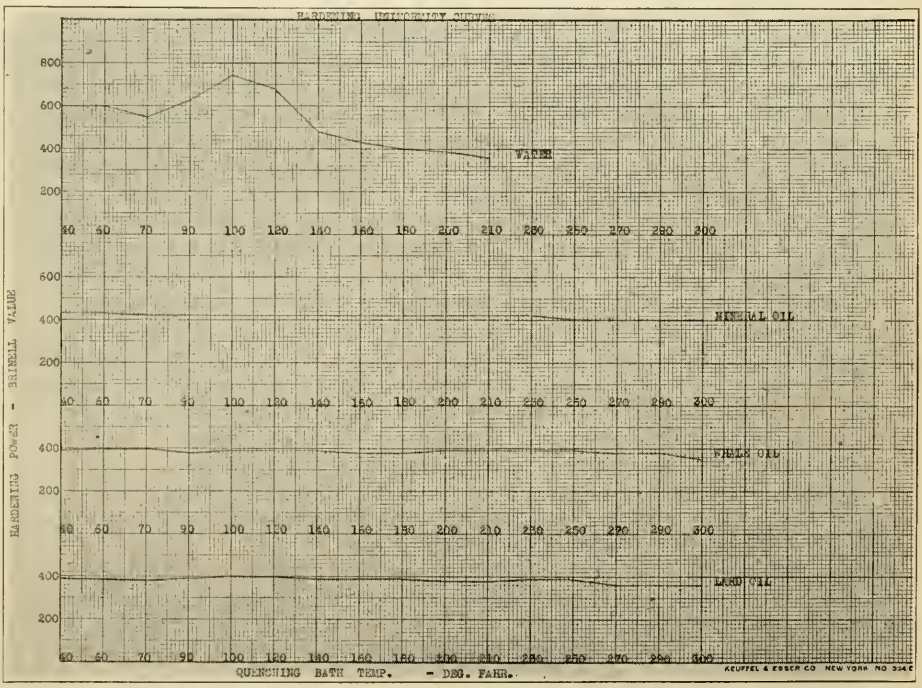
Notwithstanding, however, if the mineral oil is not subjected to severe usage, it would appear that it can be introduced into small establishments without bad results.

Compounded Oils

Numerous competitors have blended oils which are held in high



Hardening Uniformity Curves



Hardening Uniformity Curves

esteem by the average heat treater. It seems only natural that an oil which is compounded for a specific purpose should possess properties which are designed for the end in view.

The compounded oils not only show excellent hardening efficiency, hardening uniformity and low viscosity, but these properties remain intact after the oil is subjected to high duty.

Operating Data

Analysis of steel used. .....

Carbon	.89
Manganese	.55
Phosphorous	.03
Sulphur	.03
Silicon	.15

Dimensions of test speciments 7/8″ round by 1/2″ long.

The quenching bath was used still, free from circulation.

Volume of quenching medium, 5 gallons.

Steel quenched from 1475° F.

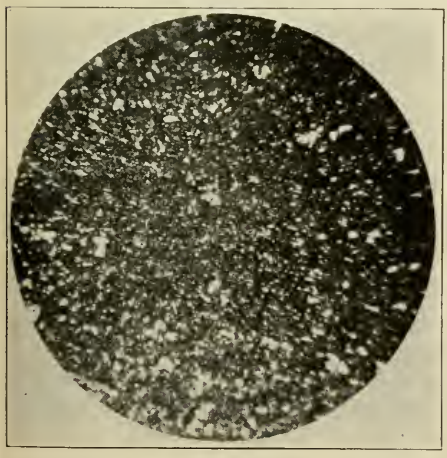
Quenching in High Speed Salts

The quenching of high speed steel in a molten chemical compound at a temperature of 1150° F. is productive of excellent results. Such a method of procedure serves a dual purpose, namely, the quenching and the drawing operations are combined.

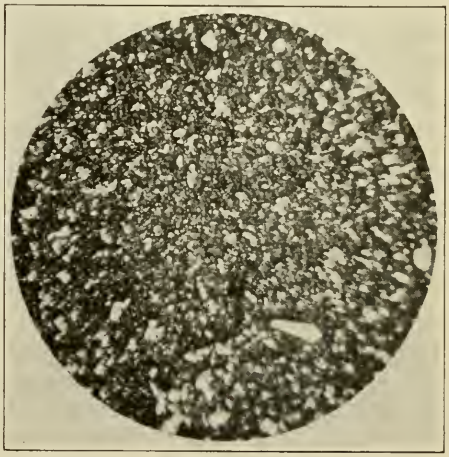
The treatment consists in heating the high speed steel to the desired temperature (22-2350° F.). The heated tool is then plunged into a molten quenching bath.

Another advantage incident to the above manner of quenching is that the tools after heat treatment are free from scale. Tools hardened in this way are also less likely to warp.

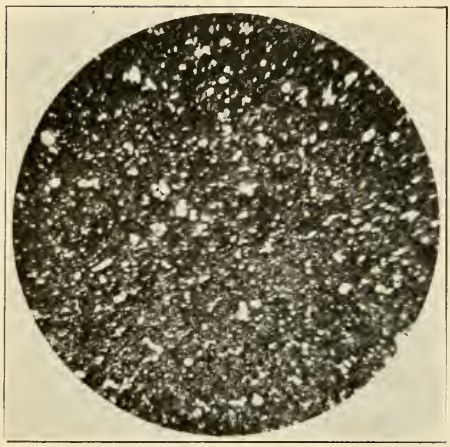
A set of microphotographs are embodied in this paper.



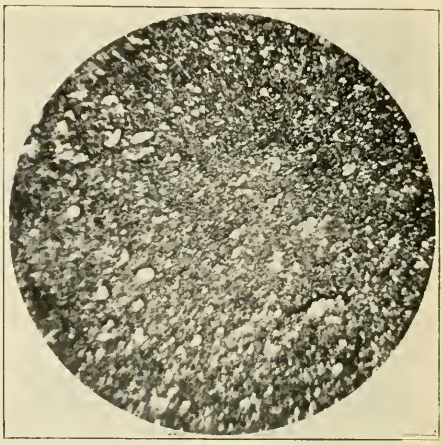
No. 1—High Speed Steel
Mag. 525× — 5% Nital Etch 7 mins.
Heated to 2,250° F.
Quenched in High Speed.
Steel Salts at 1,150° F.; then removed and cooled in air.



No. 2—High Speed Steel
Mag. 425× — 5% Nital Etch 7 mins.
Heated to 2,250° F.
Quenched in Molten (1,150° F.)
High Speed Steel Salts; then air cooled.
Drawn back to 1,150° F. in High Speed Salts.



No. 3—High Speed Salts
Mag. 425× — 5% Nital Etch 7 min.
Heated to 2,250° F. Quenched in High Speed Steel Salts at 1,150° F. Then quenched in Compounded Oil.



No. 4—High Speed Steel
Mag. 425× — 5% Nital Etch 7 mins.
Heated to 2,250° F. Quenched in Compounded Oil. Then drawn back in High Speed Steel Salts at 1,150° F.

Remarks:

The results of these experiments would indicate that eminently satisfactory results can be obtained by combining the quenching and drawing operations in the heat treatment of high speed steel. Except for a few coagulated carbide areas, all microphotographs show nearly the same micro-structure. Print No. 4 gives evidence of a finer carbide formation, which is due possibly to the fact that the transformation was arrested more rapidly. It is unfortunate that the results of practical tests could not accompany this paper, altho sufficient data has been divulged to incite further investigation.

DISCUSSION OF MR. HILLMAN'S PAPER

CHAIRMAN: You have heard Mr. Hillman's paper, and I know it represents a lot of work. I am sure all of you here use oil in some stages of the game, and I rather imagine there will be lots of questions.

MR. GREEN: Mr. Hillman may be interested to know that in one of the largest plants manufacturing a certain kind of machinery today they are using water bath for quenching certain parts of their machinery, which is maintained at a temperature of 105 degrees F. Coincident with Mr. Hillman's paper two other papers have been received bearing out the actual tests of the properties of water at 100 degrees F.

MR. GILLIGAN: There is another element enters into the problem of the quenching of steel, and that is the rapidity with which you get the liquid, either oil or water, there and the velocity with which you pass through the critical range. Mr. Hillman's tests were carried out on small

sections, and still baths. Now in certain instances we have used oil sprays with high pressure, and taking the heat units away with the greatest rapidity possible, and we obtained hardnesses that approximated those with water at a temperature of 65 degrees F. Likewise, we have applied ordinary water at a pressure of eighty pounds per square inch with a fine spray and obtained hardness that approximated brine, but we avoided cracks by discontinuing the quenching operation at an elevated temperature. In other words, I think that the results that will be obtained will vary with the method of applying the quenching medium. That is set forth in considerable detail in the Transactions of the British Iron and Steel Institute on or about 1908.

CHAIRMAN: I think, following up the same line of argument, quite a little work was done in Holland about the year 1900.

MR. GILLIGAN: At one of the meetings of the Iron and Steel Institute in Great Britain, I think it was in the 108th Volume, it carries about 150 pages of matter, criticisms and papers presented.

MR. GRAHAM: There is one point in the paper that I would like to call attention to, and that is the question of quenching in hot water, or in a water bath covered with a film of oil, that is, half an inch, or two inches deep, or whatever the amount that may be put on it. Now there are a lot of you wonder why a tool hardener quenches a piece of steel in a water bath and then quickly takes it out and puts it in oil. I know I have heard a lot of argument pro and con from practical men, and they have never been able to give a real reason for it. Some don't believe it is the right practice. Now the actual reason, as I understand it, is that the quenching speed of the bath through the different ranges affects the breakage of the steel. You can quench through the critical range without the danger of breaking, but your breakage takes place below that. With an oil bath the rate of cooling is more or less uniform down to a low temperature, several hundred degrees Fahrenheit, while with the water bath this is not the case. You cool quickly through the critical range and the rate varies, and although you may start with hot water, which cools through the critical range at approximately the same speed as the oil, the speed varies when you are cooling thru the lower ranges, and it is at the lower ranges that the cracking takes place. Therefore, as I see it it is foolhardy to quench through oil into water and expect to eliminate breakage, because you may do away with the first shock, but you are not eliminating the real cause of breakage, and that is the cooling of the steel through the ranges below the critical range, that is, through eight hundred to six hundred and four hundred, down as low as that. There have been investigations carried on along these lines that I don't know whether they have been published or not, and that has been shown conclusively to be the case.

There is another point regarding the use of oil that was brought up in one of our recent meetings in New York, and by a speaker who has done considerable investigating with the different quenching oils, and he made the statement, which is rather a broad statement "that he didn't care what kind of oil it was that was used as a quenching medium; that he could get good results with that bath if the temperature was kept uniform," and I believe that to be absolutely true. Of course the question of deterioration of the oil is another one. If you have an oil that breaks down it is uneconomically used, but starting with a new bath and two different kinds of oil, if the temperature of those baths are kept uniform,

you can obtain results that are very nearly the same, and in the ordinary run of work you cannot tell the difference. I think that that is something that the Steel Treaters should bear in mind, because you hear so many arguments just as the speaker said, about the different patent compounds and oils, etc., that confuse you; of course, in choosing an oil you want an oil that will give you the results in the long run; I am not talking about that at all; we want an oil that will stand up, but I should think that should be borne in mind.

MR. McKILLIPS: I have attended a number of these meetings from time to time, and this is the first that I have ever attended that I have been known to talk. If I were to write a paper on the heat treatment of steels, I would emphasize greatly the matter of oils. I would like to say here I have had years of experience along the line that might interest perhaps some of you, and that before I ever got to using pyrometers we used to use a method of testing or heat treating similar to this: we would take a piece of steel of a given size and weight, made identically the same, heat it and then take a given quantity of water, say a pint of water, and put that pint of water into a vessel; take this piece of steel and drop it into that pint of water; we would take the low temperature quenching water, which we will say is about 70, take the piece of steel out of the fire, drop it into the pint of water, and that would perhaps raise the temperautre up we will say to 120 degrees, showing you a difference of 50 degrees. We used to take that difference—I don't know where they got this rule from; it was a rule figured out by Mr. Hadfield—and multiply it by thirty. That will show us that we had a temperature of 1500 degrees. Well, I worked along that line for a long time until I began to see that that was anything but satisfactory, and I would go off to one furnace to make a test that I knew was considerably higher than the other, and I would get still a higher reading. I couldn't tell for a long time why that was. I am saying this just to bear out the speaker's theory on the high and low temperature of the quenching baths in relation to heat. I will say you can take a piece of steel out of the very same fire that read 1500 degrees, put it into the same quantity of water with a temperature of 90 and instead of getting a difference of fifty you probably wouldn't get but a difference of forty, which would only show you had 1200 degrees of heat, where previously the same fire showed you had 1500 degrees. Well, I thought that over and fought it so until they thought I was on the wrong track in bucking it, and I finally, rather than do that, threw up the job. Finally it came to me "How could I prove that thing wasn't right?" It dawned on me all at once that if I took water at 212 and dropped the piece of steel in there I would show that I had no fire at all. (Laughter). Now that is very true, I think, and it is one of the most important things that we have in the heating of tool steel.

Lots of people tell you about pyrometers and lots of people tell you about furnaces, but we don't spoil a lot of our work. A lot of your trouble is in the quenching. The quenching of the thing means in my estimation quite a lot.

CHAIRMAN: One of the largest steel companies in this country with quite a nice pyrometer outfit is still using that method of measuring temperatures, and relying on it to the extent they accept it in preference to what I consider as good a pyrometer as there is on the market. If there is a difference between them they take the calorimetric readings instead of the pyrometer readings.

MR. BUCKLEY: In regard to water quenching, there is one feature that the steel men don't take into consideration, and that is that you will notice from Mr. Hillman's chart as he starts at 70 and works along until it finally dropped—I have not the figures with me—I don't know just exactly what they were—that he gets the peak at about 100 to 110. Now there is a reason for that. The reason for it is that water at 100 to 110 will absorb heat very much faster than at any other temperature. Now after he drops from 110 down you will notice that he is getting something that will hold it up, because as the water gets hotter it slows down in quenching speed. That is one reason why oil is more even in its action than water.

Now there is another feature. He starts his bath at 100 but he cannot harden but very little steel before he gets up above that. Now he has to have some way in which he can circulate his water and keep it at about that temperature. I just want to say another word in regard to Mr. Hillman's microphotographs. Perhaps some of you will think that they weren't quite as fine as they might be. I made those treatments myself; Mr. Hillman made the microphotographs. It was high speed steel, heated to 2250. We quenched in salt and went through four different ways of doing it. The first one quenched in the salt at 1150 and when the steel got down there cooled in the air. The second one was quenched in salts, then taken out and cooled and then put back into the salts and drawn. The third one was quenched in the salts and then quenched in open oil from 1100. The fourth one was quenched direct into the oil and then drawn back at 1150. There has been some criticism on those microphotographs that they weren't as fine as they might have been. I wasn't doing laboratory work; it went through in the shop production work; consequently it didn't cost us twenty-five or thirty dollars to make them, either.

MR. MERRILL: I would like to say here I have been using my salt bath at a temperature of 93 for a good many years, and I am just as fussy over the temperature as I am over my fire. I have been using that for a number of years.

MEMBER: I don't agree with my friend Hillman on some things. We have had more or less scraps and probably will continue to do so, and at the same time be good friends. There was one article in which he says that mineral oil is all right for small shops. I say No, that the small shop needs the good stuff just as much as the large, if not more so, because he only quenches a piece now and then, and he wants an oil that will remain thin all the time. That is, when I say that, that doesn't increase in viscosity. Mineral oil will absorb moisture from the air. It will deteriorate from being open, but with the compounded oil that he speaks of it is hopeless; that is why the tests were made. The viscosity, or rather, the baume of the oil after we got through with the test was precisely the same as when we started. Now we can get an even Brinnel hardness from 70 with a drop from 430 to 418 up to 250 degrees F. Now the other oils,—there is a reason for the other oils. The vegetable oils from the fact that as soon as we commence to use it you change the nature of the oils, which is caused principally by the fatty acid in the oil that thickens up and the light end evaporates. Consequently, after you have quenched for a short time in those kind of oils, take for instance a

4. L. R. Seidell and G. J. Horvitz, "Physical Qualities of High Chrome Steel," Iron Age, vol. 103, No. 5, Jan. 30, 1919, pp. 291-294.

week's quenching, they will deteriorate very rapidly; even at the same temperatures you will get very much softer work, due to the reason that they oxidize.

MR. HILLMAN: I wish to call Mr. Buckley's attention to the fact that three of the largest manufacturing concerns in Worcester, Mass., are using mineral oils. One of them is a part of the U. S. Steel Corporation. Another is a large chain works, and the third is the Fiat Company. There has been nothing proven against mineral oil. There is no doubt in my mind but what mineral oil undergoes fractional distillation, of course, but there are a lot of the biggest concerns in the country using it.

MR. BUCKLEY: One of the three that have used the other oil claim they never had anything like it. They have gone to mineral oil, but they have five thousand gallons of the other oil saved nevertheless. In another instance of a spring concern they began using the mineral oil, but it thickened up so they couldn't pump it through the pipes at all. Those two instances both occurred in the same city.

STAINLESS STEEL
ITS TREATMENT, PROPERTIES AND APPLICATIONS

W. H. Marble*

(A paper presented at Philadelphia Convention)

"Stainless Steel" is so exploited on account of its peculiar property, when properly hardened and finished, of resisting oxidation and corrosion by the ordinary agents.

It has been stated at various times that its discovery was accidental, whereas a careful search would indicate that two men, working independently, with no knowledge of what the other was doing, actually developed this unique alloy.

In 1911, Mr. Elwood Haynes, of Kokomo, Indiana, made experiments with alloys of iron and chrome, with a view to determining the effects of chromium on the resistance of steel and iron to chemical and atmospheric influences; also its effect on the hardness, elasticity and cutting qualities of steel.

About the same time, or possibly a little later, Mr. Harry Brearley, the eminent metallurgist of Sheffield, England, discovered this alloy while working on armor-piercing projectiles for the Russian Government. At that time, he was investigating powder-erosion. His tests produced a non-erodible alloy which did not scale easily and did not tarnish when exposed to the action of many acids, including fruit acids.

The demand for a non-rusting or non-staining material for knives and other cutting tools or instruments suggested itself as a big field for Stainless, and this probably was one of its first uses. Scientific tests have since proved conclusively that a Stainless blade properly made, hardened and tempered, will take and maintain an edge equal to the best cutlery, with the added asset that it resists rust and stain.

During the late war period, all Stainless supplies in England were appropriated by the Ministry of Munitions. The bulk of this material was used for a purpose similar to that for which it was designed—exhaust valves for aero engines, which are required to be strong and resist erosion at high temperatures. Its subsequent use in this country naturally fol-

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lowed, and it has been used successfully, and in large quantities, in place of high-nickel and high-tungsten steels.

It has been stated too, that Stainless is "one of the indirect results of improvements in the manufacture of carbon-free ferro-alloys."

Previous Investigations

In 1917, Dr. W. H. Hatfield,[1] of Brown-Firth's Research Laboratory, Sheffield, England, published results of tensile and impact tests of a steel containing about .30% carbon and 13% chromium. He has also shown comparisons between air, oil and water quenching, followed by a relatively high temperature tempering. Some of his results have been incorporated in a report submitted to the joint Iron and Steel Committee of the S.A.E.[2] and A.S.T.M. This report also includes a brief discussion of proper methods of working, annealing and finishing Stainless Steel, with a chart showing the results of scaling tests with Stainless, high-speed and other alloy steels.

Messrs. French and Yamauchi, of the United States Bureau of Standards, show, in Chemical and Metallurgical Engineering,[3] some very valuable tables, giving results obtained by varying the quenching and tempering temperatures. Their results would indicate that quenching from about 1,750° F. develops the best combination of strength and ductility, although this does not give the maximum hardness; that ductility as measured by elongation and reduction of area is very low in those samples quenched from 1,850° F. and above; that maximum hardness is generally obtained at about 1,950° F.; that the most rapid change in tensile properties and hardness occurs in tempering between about 800° F. and 1,000° F.

Messrs. Seidell and Horvitz, at the present time with the New York Testing Laboratory, discuss in *Iron Age*,[4] results of experiments carried out to find the relation between hardness and double carbides in solution. These results show that with a quenching temperature of 2,150° F., a maximum hardness is produced; that after suitable drawing treatment under these conditions, tensile strength and ductility are maximum. They also show by means of photomicrographs that with minor exceptions, the micro constituents of Stainless Steel are analogous to those with which we are familiar in ordinary carbon steel.

Mr. Elwood Haynes, in an address before the Engineers' Society of Western Pennsylvania, November 25, 1919, draws these conclusions as a result of tests made during the past several years:

That an excess of 8% chromium makes the alloys practically immune to nitric acid; that these alloys could be hardened by heating to redness and quenching; that they are distinctly malleable; that the alloy was much more easily worked if the carbon content were kept below 1%. He also states that its immunity to acids is due primarily to its composition; that, although quenching in water enhanced its resistance to a considerable degree, it is best to use oil for quenching, in order to avoid local contractions and stress in the finished product. His tests have shown that air-cooled forgings show a remarkably fine grain and good cutting qualities,

1. W. H. Hatfield, "Heat Treatment of Aircraft Steels," Automobile Engineer, 1917, vol. 7.

2. Journal of the Society of Automotive Engineers, vol. 5, No. 3, September, 1919, pp. 262 and 263.

3. H. J. French and Yoshito Yamauchi, "Heat Treatment of a High-Chromium Steel," Chemical and Metallurgical Engineering, vol. 23, No. 1, July 7, 1920.

depending upon the exact composition and the highest temperature up to which it was heated before hammering, and that, notwithstanding the comparatively high temperatures of working this steel, the bars show almost no scale during the forging operation. By increasing the carbon content of these alloys, they can be rendered sufficiently hard by quenching to scratch glass. Small castings can be made by the use of chill molds.

Chemical Composition

The selection of a standard analysis has been the result of countless tests that showed generally that, within certain limits, stainlessness is increased with the increase of chromium and the decrease in carbon content.

Carbon	.20 to .40%
Chromium	11.40 to 14%
Manganese	not to exceed .50%
Silicon	not to exceed .30%
Sulphur and Phosphorus	as low as possible.

The question of increasing the carbon point, as well as the effects of a higher silicon content, have been rather exhaustively investigated, but with no subsequent change, for the present, from the foregoing analysis.

A brief resumé of the effects of certain elements upon the various properties of the alloy may be of interest.

Effects of Various Elements

Carbon.—The carbon content usually found in Stainless Steel is .25 to .40%. Under .25% the steel will not harden successfully, while above .40% it is difficult to forge and begins to lose its non-corrosive property. Properly hardened Stainless of correct composition is a martensitic structure with numerous globules of double carbides of iron and chrome present. The steel varies in hardness in direct proportion to its carbon content.

Chromium.—Chrome is the most important element and is practically the only alloy used. It is from the chrome content that Stainless derives its resistance to the various oxides and corrosive agents. Chrome forms carbides with the carbon, which compound not only furnishes the requisite hardening properties, but is in itself one of the most difficult substances known to oxide or corrode. Pure iron is also known to show great resistance to acids and oxidizing conditions, and as hardened Stainless is theoretically a matrix of iron containing chrome carbides, the combination furnishes an alloy which is highly resistant to stain or rust.

Silicon.—Silicon neutralizes the hardening effect of carbon, thereby making possible the use of a much higher carbon content. It has a tendency to remove gaseous impurities and oxides which assists in the formation of a sounder steel mass, free from slag, seams and blow-holes. To offset these desirable properties, however, the silicon retards hardening and increases brittleness. Stainless containing high-silicon cannot be hardened to the same extent as can the same steel without it. It is best then, to keep the silicon content low.

Sulphur and Phosphorus.—Sulphur and phosphorus are injurious in that they assist in the formation of an electrolytic action which induces corrosion. They also have a tendency to segregate. These elements are impurities and should be kept as low as possible.

Manganese.—Manganese counteracts the injurious effects of sulphur by forming sulphides in which formation sulphur does not show a marked tendency towards "red shortness." The manganese content should be kept

low, although a small percentage is necessary to assist in hardening.

Other elements such as nickel, copper, cobalt and tungsten have been used in Stainless Steel, but it is doubtful as to whether any great benefits have been derived from their use. The addition of tungsten and nickel so far as it is known, serve only to increase the luster of the polished section.

Manufacturing

The manufacture of Stainless Steel is in a general way very similar to that of high-speed steel. It is melted in two general types of furnaces, known as the Crucible and Electric, the process of operation and construction of which are no doubt familiar to everyone. The steps leading up to the actual heat treatment can be stated briefly.

After the ingots have been cast and allowed to cool somewhat, they are "box annealed" at a temperature as near 1,380° F. as possible, for a period of about 13 hours. They are then allowed to cool slowly to atmospheric temperature. This is most important, for Stainless, like high-speed steel, is air-hardening. Ingots before forgings are usually planed to remove all surface defects. The material will machine very easily after the annealing operation.

Forging and Rolling

Before forging the ingot should be heated slowly up to a temperature of from 1,650° F. to 2,100° F. It should be cogged down by easy stages, care being taken that the temperature does not fall below 1,650° F. If the steel is worked below these temperatures, it is liable to be ruptured or broken under the heavy blows of the hammer. A noticeable feature of this operation is the very inappreciable amount of scale formed. The steel will be hard if allowed to cool in the air after forging, the hardness depending upon the exact composition of the material and the highest temperature up to which it was heated before being finally hammered. This hardness may vary over wide limits—to correspond with a Brinell hardness of 500 if the temperature before hammering was as low as 1,800° F., or to a Brinell hardness of only 250 if the temperature before hammering had reached 2,000° F.

Annealing

One of the characteristics of this steel is that if heated to a temperature of 1,800° F. and allowed to cool quickly, it becomes hardened. Consequently, after forging it must be annealed before it can be machined. Stainless Steel should be annealed about the same as high-grade tool steel, except that the heat should be about 1,400° F. A good way is to heat the steel in pipes, and cool pipe and steel very slowly in a pit, or to heat it up to about 1,400° F. in an open furnace, then close up the furnace and allow the steel to remain there while the temperature drops slowly to 1,100° F. Then take the steel out and allow it to cool naturally in the air. After annealing, it will have a hardness of approximately 200 Brinell and machines easily. Should a softer condition be required, heat to 1,560° F. or 1,600° F., and follow by very slow cooling.

Hardening

This material may be hardened in air, oil or water. A good hardening temperature is somewhere in the vicinity of 1,750° F., quenching in oil or water, or cooling in the air depending on the size or shape of piece treated. The steel should be tempered back to suit the work or results desired as

with any other alloy steel. If the higher hardening temperature is chosen, it will require a correspondingly lower tempering temperature—the reverse of a carbon steel.

Temper Colors

Temper colors appear at approximately twice the temperature of ordinary carbon steels, for the higher heats, so that the temper should be drawn to a definite temperature in a bath or furnace instead of drawing to a color. A good tempering temperature for a knife blade is about 280° F. to 300° F., but for a valve it would be necessary to go as high as 1,100° F. These colors are due to very thin films of oxidized metal. As Stainless Steel resists oxidizing, it requires more heat to produce a given color than ordinary tool steel, as is illustrated by the following table, the temperatures of which are only approximate.

Color	Appears on Stainless Steel (Degrees Fahrenheit)	Appears on Tool Steel (Degrees Fahrenheit)
Faint Yellow	....	430
Light Straw	575	450
Dark Straw	660	475
Purple (Reddish)	750	525
Purple (Bluish)	850	550
Blue	1,000	575
Gray Blue	1,100	600
Greenish Blue	1,300	625

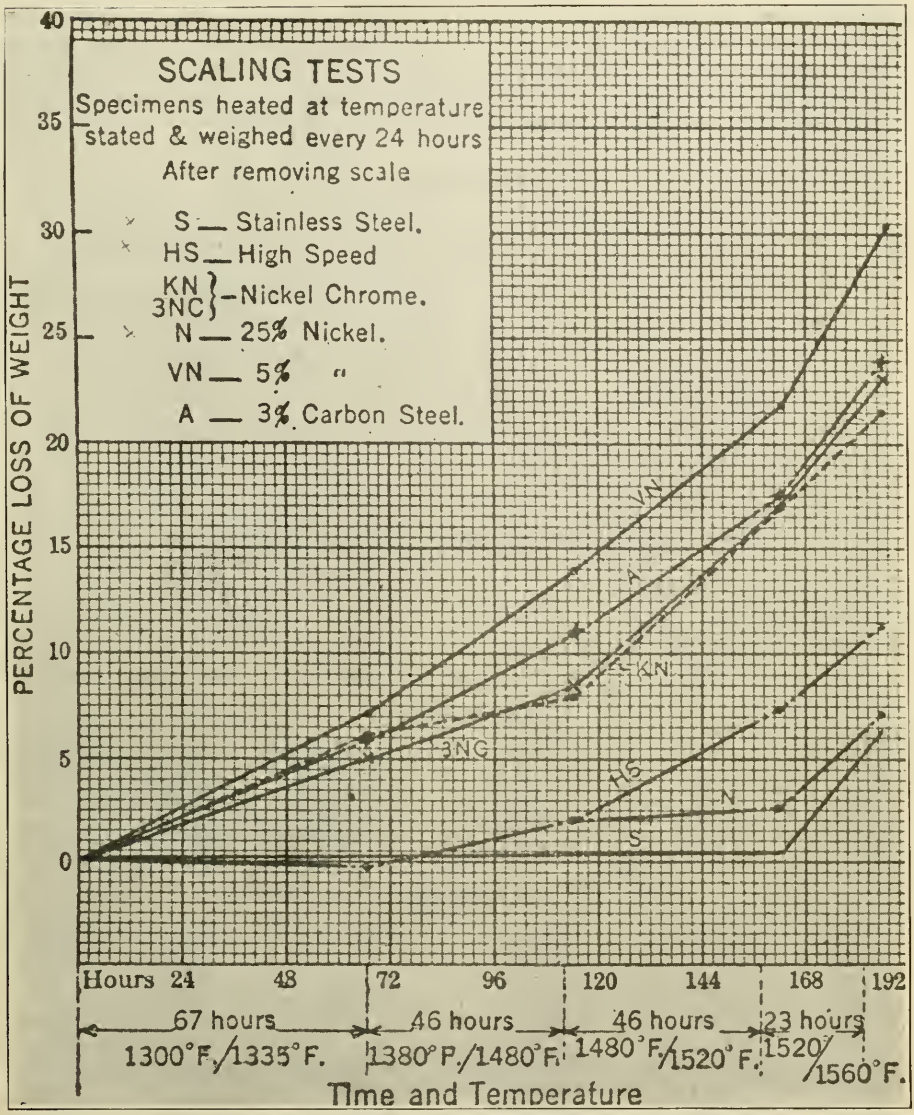
Scaling

As the temperature of ordinary steel rises, the surface oxidizes into a scale of measurable thickness and even at a low red heat, the thickness of the scale increases with time. Stainless Steel behaves quite differently. Up to a temperature of about 1,520° F., the gloss surface due to polishing and hot tinting is permanent, and the specimen neither gains nor loses appreciably in weight. Its comparative value in this respect is illustrated by the following chart which records the percentage lost in weight of various steels after exposure for many hours at temperatures above red heat.

Corrosion

The steel's power to resist stain does not reside in any finish which may be applied by the manufacturer, but in the hardened steel itself. However, rough the surface of a hardened, hardened and tempered article may be, if it is a clean metallic surface and has not been distorted, it will be rustless. However, to exercise this feature to the best advantage, a really good ground polished surface should be provided. Where the highest possible degree of resistance to corrosion is essential, it is recommended that the parts be drawn back very slightly after hardening, and that they then be polished free from scale marks, hair lines or other surface imperfections. These imperfections if left, serve as nuclei from which corrosion is apt to spread. This process is essential only where the bright color of the polished metal is desired to be permanent.

Stainless Steel does not corrode when in contact with other steel. It is, however, attacked in an otherwise non-corroding liquid when in direct metallic contact with copper or copper alloys, such as gunmetal.



Etching.—A mixture of nitric and hydrochloric acid will etch Stainless Steel; hydrochloric acid alone in which copper sulphate has been dissolved, serves very well for light etching. The use of a mixture of nitric and hydrochloric acids might create fumes which are objectionable, in which case it is good commercial practice to use a saturated solution of ferric chloride in hydrochloric acid. Another etching solution consists of two parts of 50% solution of hydrochloric acid; two parts of 15% solution of Ammonium persulphate, and one part of a concentrated alcoholic solution of o-nitro-phenol.

Cold Working

Cold working of Stainless Steel destroys its stainless property, and

unless it is heat-treated subsequently to restore it, it is useless to put cold-pressed parts into use necessitating its resistance to corrosion. The heat-treatment necessary to restore the stainless properties of cold-worked Stainless Steel is by hardening and tempering. Hardening will necessitate bringing the steel to a temperature of about 1,650° F. Care should also be taken that the material or parts be thoroughly annealed between successive operations.

Physical Properties

The physical properties do not vary greatly when the carbon is within the usual range of composition, or when the steel is hardened and tempered in air, hardened and tempered in oil or water.

A comparison of these properties is shown below, under conditions of air, oil and water-hardened steel of the following composition:

Carbon	.240
Manganese	.300
Phosphorus	.035
Sulphur	.035
Chromium	12.850
Silicon	.200

Heat Treatment—Mechanical Properties

Hardened from Degrees Fahr.	Tempered at Degrees Fahr.	Elastic Limit	Tensile Strength	Elongation Per Cent	Reduction of Area Per Cent
		Air Hardened			
1650	930	158816	192416	13.0	40.5
1650	1100	99680	120064	21.0	59.2
1650	1300	70784	101248	26.0	64.6
1650	1380	66080	98336	28.0	63.6
1650	1470	70784	96992	27.0	64.7
		Oil Hardened			
1650	930	163072	202720	8.0	18.2
1650	1100	88256	116480	20.0	56.9
1650	1300	77952	105504	25.5	63.8
1650	1380	88256	98784	27.0	66.3
		Water Hardened			
1650	830	158816	202048	12.0	34.2
1650	1100	90272	120736	22.0	59.8
1650	1300	66080	102592	25.8	64.7
1650	1380	67200	97888	27.0	65.2

(The above tests were drawn for one hour at the noted temperatures and allowed to cool in air).

This steel has a co-efficient of expansion of .00001091512, which is slightly less than ordinary steel.

Applications

Cutlery.—Knives made of this steel are in all respects quite equal to those made of the best qualities of cast steel, besides having the advantage

of being stainless. The composition of about 13% chromium and .30% carbon is used. Dr. W. H. Hatfield[5] is authority for the statements that Stainless Steel could be hardened far in excess of actual requirements for table knives, carvers, pocket-knives and razors. To get such results, the steel should be hardened from temperatures of 1,740° F. to 1,830° F., or about 250° F. to 300° F. higher than the usual temperatures necessary in the hardening of high-carbon cast steels. Successful tempering can be accomplished by placing the knives in an oil bath for 5 minutes, the oil of which is maintained at a temperature of about 355° F.

Valves.—Valves have been generally made to meet the following specifications, in the annealed condition:

Yield Point, pounds per square inch	70,000
Tensile Strength, pounds per square inch	90,000
Elongation in two inches	18%
Reduction of Area	50%

The usual heat treatment is to quench in oil from 1,650° F. and temper or draw at 1,100° F. to 1,200° F. One manufacturer hardens valves by heating the previously annealed valves to 1,650° F. and cooling in air. This gives a Scleroscope hardness of about 50. Should a greater degree of hardness be desired it can be obtained by heating to 2,000° F., cooling in air. This gives a Scleroscope hardness of about 75.

Besides its use for cutlery and valves, the purposes to which Stainless can be applied are legion. The fact that nickel steels containing a high percentage of nickel, are difficult to machine, opens up a large field for Stainless, in that it can be readily softened for machining purposes and afterwards suitably hardened to resist wear and stress. As this material is very difficult to deform, and is not easily eroded at temperatures up to 1,500° F., it is an excellent material for the manufacture of hot dies, extrusion dies, punches and moles for die castings.

Other engineering applications of the alloy may be mentioned—turbine blades, pump rods and valves, acid pumps, rams, evaporating pans, races and rollers for ball bearings, refrigerator machinery. Several instances might be cited where turbine and pump parts have maintained their bright appearance, with a very inappreciable amount of corrosion, after having been in use for several years. Due to the extreme toughness, ability to resist abrasian, and its mirror-like finish, moving parts made of this alloy wear longer, and, due to the reduced amount of friction, require less repacking. Since the steel is affected only slightly by salt water or salt air, it may be employed for a variety of marine purposes.

In the electrical field, Stainless Steel is used for permanent magnets and for electric cooking stoves and utensils, where the advantages of permanently bright and clean surfaces in assisting the reflection of heat and consequent economy of current are immediately apparent.

CONCLUSION

This steel is costly to produce in the form of cutlery by reason of the necessity for better grinding and more careful forging in consequence of its great hardness. For general use, it may be said that it is costly to manufacture by reason of the expensive alloy employed, and the comparatively heavy waste (due to scrap) involved as a result of very careful inspection; but there *is* a very wide field of usefulness before it.

5. Dr. W. H. Hatfield, "Cutlery—Stainless and Otherwise," December 17, 1919, reviewed in the American Cutler, June, 1919.

DISCUSSION OF MR. MARBLE'S PAPER

Chairman: Mr. Marble informs me that Dr. Johnson will reply to any discussion along these lines, so you will now have another opportunity to discuss this same subject as was first presented, as well as the points that Mr. Marble brought out. We now have ten minutes for discussion.

Mr. Hupp: I would like to ask Dr. Johnson what has been the results of experiments in treating the acid-resisting cutlery in a solution of sulphuric acid around a temperature of boiling water?

Dr. Johnson: All the value of acid resisting is secured at low temperatures. That is, you are speaking now of the first paper I take it. I would say that the stainless steel is not much in resistance to sulphuric acid. None of that type of steels are. But the other type I mentioned offers very considerable resistance at low temperatures, but if you apply heat then your resistance begins to fall down very rapidly. The value of low temperatures for resistance is well known; if you have something you are not intending to apply heat to it comes in very promisingly there. If you apply heat the resistance begins to break down.

Mr. S. J. Sharpe: I would like to ask Dr. Johnson if this steel would be suitable for etching on such as textile work?

Dr. Johnson: The other type of acid resisting, flame resisting, and non-magnetic offers very considerable resistance at ordinary temperature.

Mr. Sharpe: Would you consider this a good grade of steel for manufacturing mills of that purpose? It is etching with sulphuric acid.

Dr. Johnson: The stainless steel will etch all right, but the flame and acid resisting will not etch with sulphuric.

Mr. Sharpe: It would stand up, though. We use now about a .40 carbon steel for these mills. We have quite frequently a break-down on the surface after having the pattern for the mill all etched. Maybe we will use it about fifteen or twenty minutes and one spot will break down. Now whether or not this stainless steel would stand up after tempering or case hardening better than the average .40 carbon steel is what I want to get an answer to. After you have etched the pattern on it and hardened.

Dr. Johnson: I would say, yes.

Mr. D'Arcambal: During the war we used stainless steel valves for the Hispano-Suiza Motor, and we found by heating the valves up to 2100 and quenching in oil at 1400 we got very good results.

Dr. Johnson: That would be all right up to two thousand Fahrenheit; I would say it is perfectly safe for stainless steel at that temperature. In the first paper we showed photographs of stainless steel breaking down up above two thousand degrees. It is perfectly safe, however, up to that point I would say.

Mr. DeVrees: The last speaker has mentioned double carbide chromium, in the .30 carbon, .13 chromium stainless steel. Now I must confess that I don't believe he knows anything about that, but I would like to ask him if he has isolated those carbides? If he really has done it it would be extremely interesting, because it seems to me that when you have free carbides in a mass of material that those are going to be electro-positive or electro-negative to the surrounding ground mass of the steel, and would, naturally, when you put electrolite like sulphuric or nitric acid or salt water on there, form rapid points of attack. Now if he has any information on that I would be very glad to hear it, because it has been

stated there are no microscopically detectable free carbides in that kind of steel. If he has some later information I would like to have it.

Dr. Johnson: I would say that I will give no opinion one way or the other, because I have made no attempt to separate these. In fact, I don't know whether Mr. Marble has any information on that or not, but that is my remark. Now whatever Mr. Marble may say on that is up to him.

Mr. Marble: I think I can show the gentleman my authorities. I have authorities for my statement. Mr. Seibel of the New York Testing Laboratory is one.

Member: I may mention in that connection that I was at the New York Chapter meeting when Don Clark, I believe it was, read a paper along very much the same lines as the last speaker, and I brought up the same question, but I got no information. This is not a question that I am asking for any reason except it seems to me that it is very interesting in connection with the rusting and the staining of the steel. If we get a lot of free carbides there it is evident they are going to be either electro-positive or electro-negative to the surrounding ground mass, and since the speaker said there were double carbides of chromium there, which I very much doubt myself, because there is only .30 carbon in the steel, and with that in the steel it is very evident to every metallurgist you cannot get much of the cromium to unite with the carbon. It is almost self-evident that although cromium in itself is an element that goes with the carbon in the steel and likes to form carbides when it has a chance, it is not going to have much of a chance when there is only .30 carbon there to form it with.

Dr. Johnson: As I said before, I have made no tests on this and can only give a supposition, and I am free to say I wouldn't be surprised if you defined those carbides, but it is only a supposition. In the structure shown in the picture it would perhaps show an indication of carbides.

DISCUSSION OF MR. TROUT'S PAPER

Published Vol. I, No. 1. Page 51.

MR. COX: Would the producer gas installation be economical for a consumption of about three million cubic feet of gas a month?

MR. TROUT: You have got to get that down to terms of the hour—it would be about a thousand feet an hour?

MR. COX: It would be about 1,000 feet per hour for each furnace, and we have ten of them.

MR. TROUT: There is an economic condition there. You could produce your gas with an over-all cost of about 47 to 50 cents.

MEMBER: You have cited several tests against oil, and if I am correct you gave the B. T. U. input considerably in favor of gas in each case. Am I correct in that?

MR. TROUT: Yes.

MEMBER: Now in your paper you made the statement that the flame temperature of oil was considerably greater than producer gas.

MR. TROUT: I didn't say that. I said that on account of the high temperatures it is easier of application, referring to oil.

MEMBER: That being the case, assuming, for instance, that the oil has a higher temperature, how do you account for the difference in the B. T. U. input?

MR. TROUT: It seems to follow that a gaseous fuel is more efficiently applied to a furnace than a solid fuel.

MEMBER: That being the case, now is it a case of application more than it is a case of the fuel used?

MR. TROUT: Admitted.

MEMBER: That was the point I wanted to make, that it wasn't the fuel but the application. Now in the test you made you mentioned the fuel going in and what came out, but did you know that your oil fire was not excessively over-ventilated and that you were losing your heat through over-ventilation?

MR. TROUT: These tests were made by the engineers of the automobile plant and sent in to us. They were supposed to have been made with all care taken of that. I will be glad to show you a copy of it.

MEMBER: Now I am not boosting any particular fuel. We are a firm of hoisting engineers. The point is so often made that there is an economy in a particular fuel, and our experience is that there is no particular economy in any particular fuel except as caused by local conditions in the price of the fuel. Seventy-five per cent of the cause of fuel economy lies in the application to the individual plant.

MR. TROUT: There is some difference due to heat liberated through different processes of application. It may be possible to apply oil through some of the newer types of burners and methods of gasifying that oil before entering the furnace that would give you as high efficiency B. T. U. for B. T. U. as we now get with gas applications, but with the ordinary application in the many plants that we visit that is not the case.

MEMBER: I know you are correct in that statement, but it would seem to me from my observation, and I have followed this game for possibly twenty years now, that as far as a matter of application to the plant in steam boiler work is concerned, we can secure a greater over-all efficiency with oil than we secure with any other fuel. I am not boosting oil, either, but we get the highest over-all efficiency with oil that we do with any fuel. We get it because we have a good application.

MR. TROUT: Maybe you have not applied the other fuel as efficiently as you do the oil.

MR. YOULE: That is entirely possible, but we get our efficiency in oil from flame temperature in that case.

MR. TROUT: I don't think that would be true in the case of the paper under discussion with heat treating furnaces.

MR. YOULE: Oh, no, I didn't mean to give that impression.

MR. ROCKWELL: I would like to ask how you take care in a small producer plant without a gas set?

MR. TROUT: The construction of the plant is such that the gas exhauster which is used in connection with bituminous coal or on anthracite where the gas is used for fuel purposes, there is a gas exhauster installed in each plant and that is either changed in speed by automatic control through pressure in the distributing line or else there is a by-pass around the exhauster which automatically maintains a uniform pressure in the distributing line.

MR. ROCKWELL: How does it affect the chemical properties of the gas? Supposing there was a variation in flow throughout the plant.

MR. TROUT: Practically not at all, that is, within commercial limits.

VARIOUS QUENCHING MEDIUMS AND THEIR APPLICATION

By W. G. Lottes*

(A Paper presented at Philadelphia Convention)

I wish some of the members of the committee would tell me why they asked me to read a paper on quenching medium for the heat treatment of steel. I know there are hundreds of members of this organization that are more competent than I am to read a paper on this subject. I am afraid that some of the college bred members have put up a job, as they do enjoy picking on a Freshman.

Whatever their object was, I want to tell you that it was among the proudest hours of my life when I received the invitation to prepare a paper for this, our Second National Convention, on the treatment of the most indispensable metal on the earth's surface. With it we have conquered the beast and the monarch. We have protected ourselves and our country with the pioneer's coming, the ring of the anvil, followed by the sickle that cuts the ripened grain and many other labor saving devices.

The subject of quenching medium for the heat treatment of steel is entitled to more consideration than it has received in the past, especially within the last ten years when we made greater progress than we have in any ten years previous.

First, I want to say opinions on this subject vary, similar to religious and political opinion, and some are just as unreasonable.

We have had patent quenching mediums on the market besides the many secret mixtures and the many different waters used and sold, some from certain springs, rivers and wells; rain water that fell certain times of the year or Holy Days; rain water that passed through horse barns; muddy rain water, which has some merit in preventing water cracks due to the slower cooling quality.

In the majority of cases when the tool hardener, or whoever did the heat treating, got results quenching in any of these mediums he was very careful not to tell anyone. Very often his employer did not know what he was using, but both had all the confidence in the quenching medium, to the extent that the employer felt that his hardener was one of the indispensable men at his factory. All concerned were of the firm belief that it was the quenching medium that gave them the quality that he was getting. They were just as firm in their belief as people are in their religious belief and today we have some men who make their living selling the quenching medium to the blacksmith by making him believe that it was the only safe thing to use to secure everlasting happiness in connection with the hardening of steel.

These same men are still getting converts, get the same letters of recommendation the patent medicine man gets and unless this organization exposes the many fake compounds and quenching mediums, these men are going to get what the patent medicine man was not able to extract from the people under false pretense.

It is not a difficult matter to test quenching mediums, as you will see on the curves shown on Plate No. 1, page 186.

It is also not a difficult matter to control your quenching medium by different temperatures and circulating speed.

How many of us have really gone into this to the extent that we should know what the effect would be by using water at different tem-

*Steel Expert, International Harvester Co., Chicago.

peratures compared with the special quenching oils.

The use of caustic soda or salt and at a temperature that will cool at the same rate that these oils do, beyond a doubt will give us the same results.

I do not believe there is any doubt in the minds of any experienced steel treater that the rate of cooling from the proper heat controls the hardness.

I am convinced that the rate of cooling from above the transformation point down to about 800 degrees Fahrenheit is what controls the quality of the effect of the heat treatment on all carbon steels.

I am also convinced that a 30-40 carbon steel of the larger area is not an oil hardening steel. We are limited in getting the desired hardness in oils of the larger area on carbon steels.

When quenching in water, we have better control of this by the use of soft water at different temperatures and the use of different percentages of common salt or soda mixed with the water.

For the past two years, I have done some experimenting, using hot water in place of oil; not in laboratory test but in a regular manufacturing proposition. The curve shown in this picture shows the effect of water at different temperatures compared with oil on a two inch diameter with a pyrometer couple fastened in the center. The principal object of this test was to show me the effect of quenching a piece of this area toward the center of the bar.

It is necessary in many cases that our quenching medium should be such that it will effect the steel to a greater depth than is possible to get in oil. The cooling from a heat beyond the transformation point down to about 800 degrees Fahrenheit should be sudden. From here down the rate of cooling is of less importance except for parts that must be very hard, then large uniform areas may be withdrawn from the water at about this temperature and eliminate the drawing operation, at the same time prevent some distortion.

We should figure the cost of heat treatment of steel just as we do any machine operation. In the past in the majority of cases the man who did the tempering very seldom gave the cost any thought. This you can see when you watch some of our tool hardeners for a few hours.

The Harvester Company has a great many different classes of work, in some cases it is not a question of cost as much as it is of quality, while on some of the agricultural implements it would be a waste of time and money to attempt to work to any such limits.

Either in machine operation or the heat treating operation, many machines have been designed with no intention of ever heat treating any parts of it. Until recent years when the larger tractors are used, we find weak parts on some of these machines and a very crude heat treating operation gives us an excess safety factor.

No. 2 shows a test made on 30-40 carbon Bessemer steel "I" beams $1\frac{1}{2} \times \frac{9}{16}''$, one-half of them were quenched in oil and the other half in water at 175 degrees Fahrenheit, all pieces taken from the same bar. This transverse test was made to determine just what temperature it was necessary to keep the water at.

No. 3 shows transverse test of 30-40 carbon Bessemer taken from different bars.

No. 4 shows the cooling quality of five different grades of oil.

I want to call your attention here that the No. 3 oil, which contains

some degras has given us good results after many months of constant use.

Why it is that we have so little information on the use of hot water for quenching medium and the effect of it on different grades of steel

TABLE No. 2

Heat Treatment of "I" Beam

Cultivator Stock, Section 1½" x $\frac{9}{16}$" x $\frac{9}{32}$" — .30 — .40 C. Bessemer. Pyrometer reading was 1560° F., Steel 1500° F. Water for quenching was 175° F. There were 16 pieces heated at same time from same bar with regular beams being heat treated; 8 pieces were quenched in water and 8 in oil.

Water Quenched

No. of Piece	Load in Lbs.	Deflection	Permanent Deflection	Brinnell
1	1500	$\frac{7}{32}$"	$\frac{1}{32}$"	
	2000	$\frac{7}{16}$"	$\frac{5}{32}$"	277
2	1500	¼"	$\frac{1}{32}$"	
	2000	½"	$\frac{7}{32}$"	269
3	1500	$\frac{7}{32}$"	$\frac{1}{32}$"	
	2000	½"	¼"	223
4	1500	¼"	$\frac{1}{32}$"	
	2000	⅝"	$\frac{7}{16}$"	248
5	1500	¼"	$\frac{1}{32}$"	
	2000	⅝"	$\frac{7}{16}$"	255
6	1500	$\frac{9}{32}$"	⅛"	
	2000	⅝"	$\frac{11}{16}$"	228
7	1500	$\frac{7}{32}$"	$\frac{1}{16}$"	
	2000	$\frac{21}{32}$"	$\frac{11}{32}$"	241
8	1500	$\frac{9}{32}$"	$\frac{3}{32}$"	
	2000	¾"	½"	241
		Average Set at 2000 lbs. ⅜"		Average 247.75

Oil Quenched

No. of Piece	Load in Lbs.	Deflection	Permanent Deflection	Brinnell
1	1500	$\frac{7}{32}$"	$\frac{1}{32}$"	
	2000	$\frac{19}{32}$"	$\frac{11}{32}$"	241
2	1500	¼"	$\frac{1}{32}$"	
	2000	½"	$\frac{7}{32}$"	262
3	1500	¼"	$\frac{3}{64}$"	
	2000	$\frac{9}{16}$"	$\frac{5}{16}$"	262
4	1500	$\frac{7}{32}$"	0"	
	1650	¼"	$\frac{1}{32}$"	248
	2000	$\frac{15}{32}$"	$\frac{3}{16}$"	
5	1500	$\frac{3}{16}$"	0"	
	2000	$\frac{11}{32}$"	⅛"	255
6	1500	$\frac{7}{32}$"	$\frac{1}{32}$"	
	2000	⅜"	⅛"	248
7	1500	$\frac{3}{16}$"	0"	
	1650	$\frac{7}{32}$"	$\frac{1}{64}$"	286
	2000	⅜"	⅛"	
8	1500	$\frac{7}{32}$"	0"	
	1650	¼"	$\frac{1}{32}$"	262
	2000	$\frac{7}{16}$"	$\frac{3}{16}$"	
		Average Set at 2000 lbs. $\frac{5}{32}$"		Average 258

Stock Not Heat Treated

No. of Piece	Load in Lbs.	Deflection	Permanent Deflection	Brinnell
1	1500	$\frac{13}{16}$"	⅝"	170
2	1500	$\frac{23}{32}$"	$\frac{17}{32}$"	179

TABLE No. 3

Water Quenched—Cultivator Beams

Water 175° Fah. Steel 1500° Fah.

Size of Stock 1½ x $\frac{9}{16}$ I Beam .30 — .40 C. Bessemer

Piece No.	25 lbs.	1000 lbs.	1500 lbs.	1750 lbs.	2000 lbs.	2100 lbs.	2200 lbs.	2250 lbs.	Broke
1	—	⅛	$\frac{7}{32}$	$\frac{5}{16}$	⅜	⅜	$\frac{7}{16}$	$\frac{7}{16}$	2300
2	5¾	$5\frac{9}{16}$	5⅜	$5\frac{15}{32}$	$5\frac{21}{32}$	SET ½	...	...	...
3	5¾	$5\frac{19}{32}$	$5\frac{15}{32}$	$5\frac{13}{32}$	$5\frac{5}{16}$	SET $\frac{3}{16}$	...	...	...
						1899 lbs.			
4	$5\frac{23}{32}$	$5\frac{19}{32}$	5½	$5\frac{13}{32}$	$5\frac{9}{32}$	5⅛	SET $\frac{7}{32}$	...	...
5	$\frac{23}{32}$	$5\frac{9}{16}$	$5\frac{13}{32}$	$5\frac{9}{32}$	5⅛	SET $\frac{5}{16}$	...	...	...
6	$5\frac{11}{16}$	$5\frac{29}{64}$	5⅜	$5\frac{15}{64}$	5⅛	SET ¼	...	...	...
					1925 lbs.				
7	5¾	$5\frac{9}{16}$	$5\frac{13}{32}$	$5\frac{9}{32}$	5½	SET $\frac{5}{16}$	...	...	...
					1875 lbs.				
8	$5\frac{11}{16}$	5½	5⅜	$5\frac{17}{64}$	5⅛	SET $\frac{5}{16}$	...	...	...
9	5¾	$5\frac{9}{16}$	$5\frac{7}{16}$	$5\frac{11}{32}$	$5\frac{3}{16}$	5⅛	$\frac{5}{16}$	...	...
10	$5\frac{11}{16}$	$5\frac{33}{64}$	5⅜	$5\frac{5}{16}$	$5\frac{7}{16}$	5⅛	SET $\frac{5}{16}$	...	Broke
					1775 lbs.				
11	$5\frac{11}{16}$	5½	$5\frac{11}{32}$	$5\frac{11}{64}$	5⅛	SET $\frac{5}{16}$	...	...	...
12	5¾	$5\frac{9}{16}$	$5\frac{13}{32}$	$5\frac{7}{64}$	5⅛	SET ¼	...	...	...
13	5¾	$5\frac{9}{16}$	5½	$5\frac{7}{16}$	5⅜	$5\frac{12}{32}$	$5\frac{5}{16}$	5¼	SET ⅛
14	5¾	$5\frac{9}{16}$	$5\frac{7}{16}$	5⅜	5¼	5⅛	SET $\frac{5}{16}$	...	...
	Average Weight 1964						Average Set $\frac{19}{64}$		

Oil Hardened

Piece No.	25 lbs.	1000 lbs.	1550 lbs.	1750 lbs.	2000 lbs.	2100 lbs.
				1540 lbs.		
1	$5\frac{23}{32}$	$5\frac{9}{16}$	$5\frac{5}{16}$	5⅛	SET $\frac{9}{32}$	—
					1775 lbs.	
2	5¾	5⅝	$5\frac{31}{64}$	5¼	5⅛	SET ⅜
				1640 lbs.		
3	5¾	$5\frac{9}{16}$	5⅜	5⅛	SET ⅜	
4	5¾	5⅝	$5\frac{17}{32}$	5⅜	5⅛	SET $\frac{5}{16}$
				1650 lbs.		
5	$5\frac{23}{32}$	$5\frac{9}{16}$	5⅜	5⅛	SET $\frac{11}{32}$	
					1830 lbs.	
6	5¾	$5\frac{19}{32}$	$5\frac{15}{32}$	$5\frac{9}{32}$	5⅛	SET ⅜
				1530 lbs.		
7	$5\frac{23}{32}$	$5\frac{9}{16}$	$5\frac{7}{32}$	5⅛	SET ¼	
8	$5\frac{23}{32}$	$5\frac{19}{32}$	$5\frac{13}{32}$	5⅛	SET $\frac{11}{32}$	
					1830 lbs.	
9	$5\frac{11}{16}$	$5\frac{9}{16}$	$5\frac{7}{16}$	5¼	5⅛	SET ¼
						2050 lbs.
10	5¾	5⅝	$5\frac{33}{64}$	$5\frac{7}{16}$	$5\frac{3}{16}$	5⅛ SET ⅜
11	$5\frac{23}{32}$	$5\frac{33}{64}$	$5\frac{7}{16}$	5⅛	SET $\frac{11}{32}$	
					1850 lbs.	
12	5¾	5⅝	5½	$5\frac{5}{16}$	5⅛	SET $\frac{23}{64}$
					2050 lbs.	
13	5¾	5⅝	$5\frac{7}{16}$	$5\frac{7}{32}$	5½	SET $\frac{11}{32}$
					1960 lbs.	
14	5¾	$\frac{33}{64}$	5½	5⅜	5⅛	SET $\frac{11}{32}$
	Average Weight 1838				Average Set $\frac{21}{64}$	

---

must be that some are practicing it and do not care to go in print on the subject because it has not had the approval of the S. A. E.

At our West Pullman Works we have installed an automatic hot water tempering control which has proven a success, shown at "A" in Plate 5. We also use hot water tank shown at "C" in Plate 6, where roller chain parts are hardened. Most of these have been in successful operation for nearly one year. In order to get the desired results, it is necessary to keep the temperature of the water within ten degrees Fahren-

TABLE No. 4

Oils

	No. 1 Per Gal. 58c	No. 2 Per Gal. 43c	No. 3 Per Gal. 20c	No. 4 Per Gal. 29c	No. 5. 25% Fuel Oil
Time required to cool 1½ pounds of steel from 1500° to 300°	154 Sec.	220 Sec.	135 Sec.	160 Sec.	No test run
Time required to cool one pound of steel from 1450° to 300°	155 Sec.	196 Sec.	132 Sec.	195 Sec.	165 Sec.
Time required to cool 1½ pounds of steel from 1450° to 900°	37 Sec.	45 Sec.	38 Sec.	44 Sec.	42 Sec.
Starting temperature of three gallon lot	80 Deg.	80 Deg.	80 Deg.	100 Deg.	80 Deg.
Finish temperature	142 Deg.	165 Deg.	140 Deg.	157 Deg.	162 Deg.

heit. This automatic control keeps it within five, as water will not permit of the same variation in temperature that oil will. We also get better results by circulating the water same as they do with oil by the use of air.

We also found that there is quite a difference in water. At one of our Canadian works, where we use Ontario Lake water, it acted quite different than some of the well water in the central part of Illinois, but we have overcome this variation by the use of caustic soda and a small per cent of common salt.

Plate 7 shows automatic temperature control on gas fired furnace used for the tempering or hardening of steel.

I am very much interested now to hear from members that have experimented or used water at different temperatures.

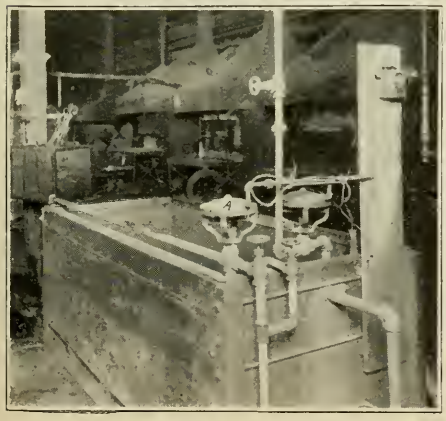


Plate 5

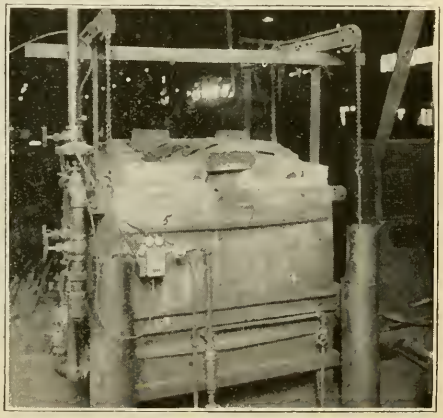


Plate 6

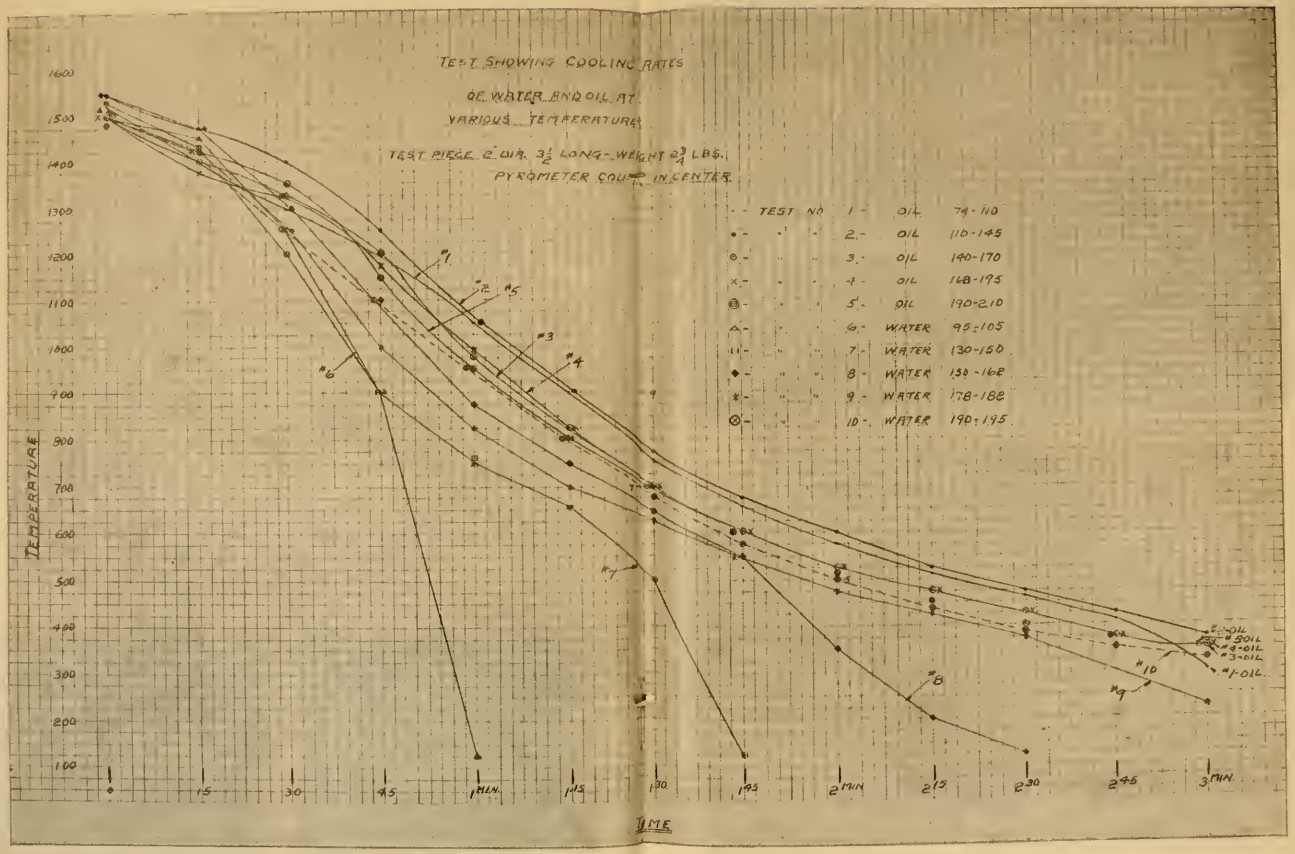


Plate No. 1. Tests Showing Cooling Rates of Water and Oil

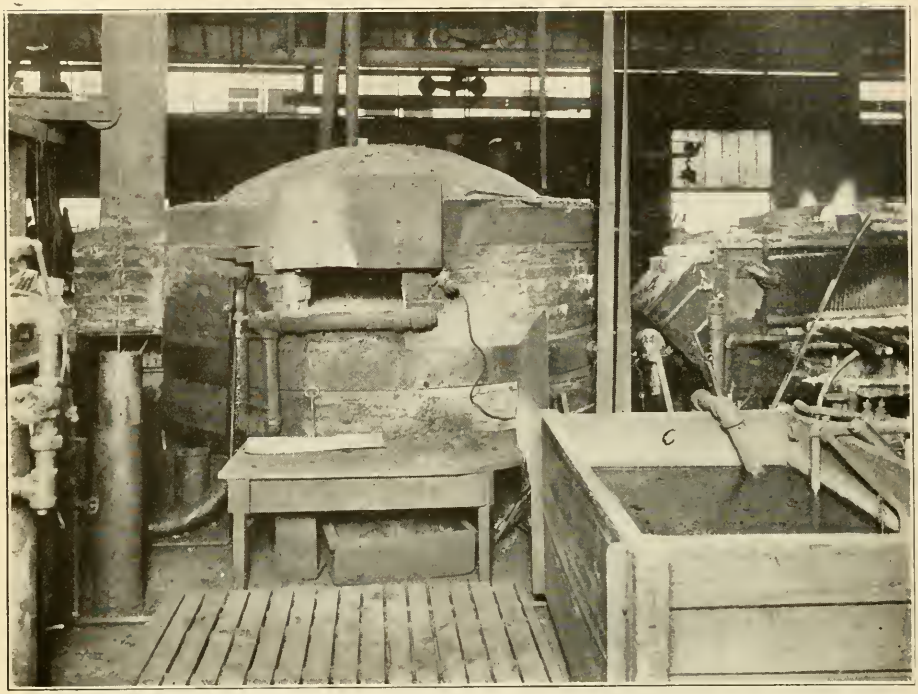


Plate No. 7

A SUGGESTED METHOD FOR DETERMINING THE COMPARATIVE EFFICIENCY OF CERTAIN COMBINATIONS OF ALLOYS IN STEEL

J. D. Cutter*

(A Paper presented at Philadelphia Convention)

Efficiency is defined as the ratio of effect produced to energy expended. The term can be applied to man or machine according to whether mental or physical energy is referred to. In this paper its application will be extended to include man, machine and material, the efficiency of a material being its effectiveness in accomplishing the purpose for which it is used considered in relation to the expenditure necessary to produce such effectiveness. An effort will be made to apply this latter idea of efficiency for comparative purposes to certain standard combinations of alloys commonly added to steel for the purpose of increasing the physical properties which can be obtained from it by heat treatment. It will, therefore, be necessary to measure the ratio of the effect produced in each case on the physical characteristics of the steel by the addition of alloying elements to the necessary expenditure for such elements. Or, in other words, efficiency is the physical properties obtainable per dollar invested in alloys.

In mechanics, both effect and expenditure are measured in units of energy, and the efficiency of a machine is represented by the fraction

$$\frac{\text{output in energy}}{\text{input in energy}} \quad \text{or} \quad \frac{\text{energy delivered}}{\text{energy applied}}$$

the value of which can be mathematically determined and expressed in

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percent. Assuming that a single mathematical expression can be found which will represent the merit possessed by a given steel with respect to the physical properties obtainable from it, and assigning Merit Index as a name for this expression, the equation for the efficiency of the alloys in that steel becomes

$$\text{Equation (1)} \quad \text{Efficiency} = \frac{\text{Merit Index}}{\text{Expenditure for Alloys}}$$

As the units employed in numerator and denominator of this fraction cannot be the same, it will be impossible to express the value thereof in percent. However, a value can be determined which will serve for comparative purposes only.

In order to arrive at a mathematical expression to serve as Merit Index for Equation (1) it will be necessary to limit consideration to tensile physical properties. Elastic Limit and Ultimate Strength are measures of the strength of the material tested while Elongation and Reduction of Area are measures of ductility or toughness. For a given amount of strength that steel is the better which has the greater amount of toughness. Conversely for a given amount of toughness that steel is the better which has the greatest strength. A Merit Index, therefore, should measure combined strength and toughness, should embrace all four of the tensile physical properties and its value should increase or decrease as the value of any one of these properties increases or decreases. An expression which fulfills these requirements follows:

$$\text{Equation (2)} \quad \text{Merit Index} = \frac{\dfrac{\text{E. L.} + \text{U. S.}}{2} \times \text{El.}}{100 \quad -\text{Red.}}$$

in which E.L. and U.S. stand for Elastic Limit and Ultimate Strength, respectively, expressed in thousand pounds per square inch, and El. and Red. stand for Elongation in two inches and Reduction of Area, respectively, expressed in percent.

An additional reason for the employment of the above expression as an Index of Merit is based on the perfectly logical idea that in cases where great strength and also great toughness are required a given material had merit in proportion to the ability of a unit mass thereof to withstand work done upon it and therefore when a test piece is broken, this merit is measured by the work done in breaking the test piece divided by the mass of the material on which this work is done.

Work equals Force times the Distance through which it moves. The force exerted in breaking a standard test piece is proportional to the Mean Breaking Strength. As it would be necessary to have the Stress-Strain diagrams of all tests and to integrate below the stress curve in order to arrive at the exact value of the Mean Breaking Strength in each case, one-half the sum of Elastic Limit and Ultimate Strength has been substituted and is closely equivalent.

The distance through which the breaking force moves is proportioned to the Elongation.

If two test pieces are examined which exhibit widely differing Reductions of Area it will be found that the one showing the smallest reduced area, namely, the one which has necked down the most, will show the least amount of metal which has suffered deformation or upon which

work has been done. In other words, the amount of mass upon which work is done in breaking a tensile test piece may be said to be roughly proportional to the reduced area or to (100 — Red), since if reduced area be expressed in percent, it is equal to (100 — Red).

Hence the Merit Index of Equation (2) is proportional to the work done in breaking the test piece divided by the mass of metal affected by such work as represented by reduced area; and is therefore a fitting index of the ability of a unit mass of the material tested to withstand work done upon it.

If the value of the Merit Index as determined by Equation (2) from a given set of physical properties obtained from tests on a particular alloy steel be divided as per Equation (1) by a figure which represents the relative value of the amounts of alloying elements present, a quantity is derived which represents the relative efficiency of the combination of alloying elements shown by the analysis. Thus without in any way endeavoring to make a comparison of prices of the various grades of alloy steels it is pointed out that by means of a simple calculation, taking into consideration the number of pounds of alloys required per ton of steel and the cost of such alloys, both of which quantities are common knowledge, a definite comparison can be obtained as to the ratio of physical properties obtainable to the cost of the alloys which make such physical properties possible.

By way of illustration, the Merit Index and Comparative Efficiency values of Figures 6 and 7 have been derived from the physical property curves of Figures 1 — 5 for the alloy steels whose analysis are shown in Table 1:

Table 1

	C.	Cr.	Ni.	V.	Mo.
Low Chrome Nickel	.36	.50	1.30		
High Chrome Nickel	.36	1.34	3.40		
3½% Nickel	.35		3.45		
Chrome Vanadium	.35	1.00		.18	
Chrome Molybdenum	.32	.90			.37

The tensile test value of Figures 1 — 5 and the corresponding analyses of Table 1 are averages of tests collected from as many authoritative sources as possible and fairly represent the physical properties which may be expected when sections approximately 1″ round of the several types of steel listed are suitably treated.

The values shown in the figures of this paper are not meant to be taken as absolute, but it is hoped that the method suggested can be used with profit in connection with the data applying in any particular case.

For much of the material from which this paper is composed, I am indebted to Mr. H. T. Chandler of Detroit, Michigan.

DISCUSSION OF MR. CUTTER'S PAPER

Chairman: We will now proceed to discuss the paper just given by Mr. Cutter. I think there are no doubt a great many who are interested in the topic which he discussed, and I hope you will be free to discuss it. We still have fifteen minutes time.

Mr. Lee of Buffalo: I would like to ask Mr. Cutter whether or not his formula has been applied to any other material than steel, and if so, as to what results have been attained.

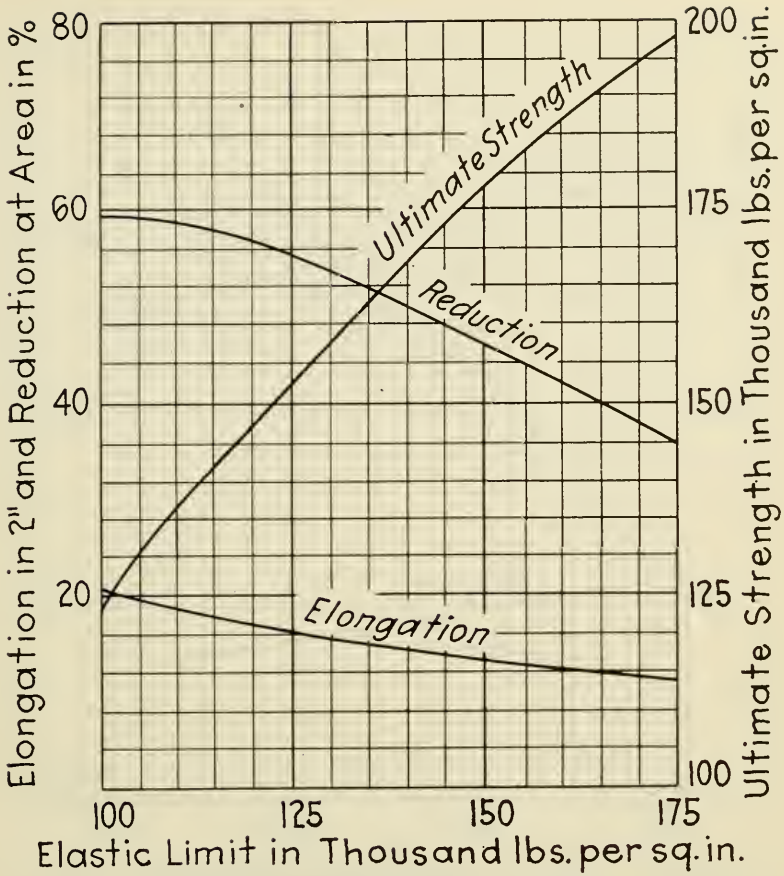


FIG. I. LOW CHROME NICKEL

Mr. Cutter: I have not applied it to any other material than steel.

Mr. Lee: It seems to me that if the thing could be worked out to apply to malleable iron and cast iron and bronze, etc., which would give a comparative value for the different types used in the different machines, it would be a step in advance.

Mr. Crowe: I would like to ask the speaker what was the highest factor of efficiency that he got on the steel tested that way?

Mr. Cutter: The efficiency Number which I showed on the screen is simply a comparative number. Unless you use exactly the same method of putting in the alloys you would not get the same number. These are not to be taken as an absolute standard by any means. I got one hundred thousand elastic limit with a low chrome nickel steel, and I got an efficiency value of 3.75, and with chrome molybdenum steel slightly higher.

Member: I would like to ask what the cost figures were that were used with the different alloys.

Mr. Cutter: I took the market quotations.

Member: They differ very greatly from the minimum to the maximum.

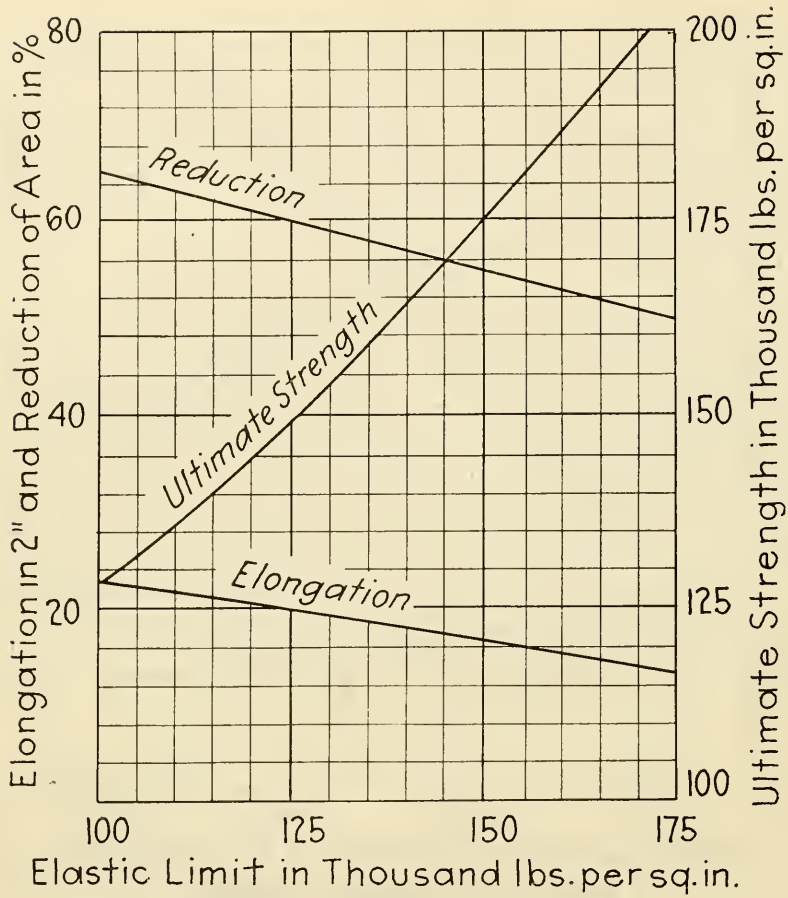


FIG. 2. HIGH CHROME NICKEL

Mr. Cutter: Sure they do. That is why I don't intend that these values should be used as absolutely fixed. They will vary from month to month as the efficiency values gotten by this method will vary also, and might be very different next year.

Member: What I mean is this: the range in price for the different alloys differs greatly. Which do you use, the maximum, the average, the minimum, or what? In the case of molybdenum it varies from $2.00 to $2.50, which do you use?

Mr. Cutter: We used the maximum in that case. Molybdenum is the only one, I believe, that has much discrepancy.

Member: There is that much in vanadium. That ranges from six dollars to ten dollars.

Mr. Cutter: We used seven dollars.

Member: You used too high a price then.

Mr. Cutter: Vanadium is quoted up to nine dollars.

Member: For this class of steel it is high. No one uses nine dollar stuff on the steel you are describing. They use the six dollar or six and one-half.

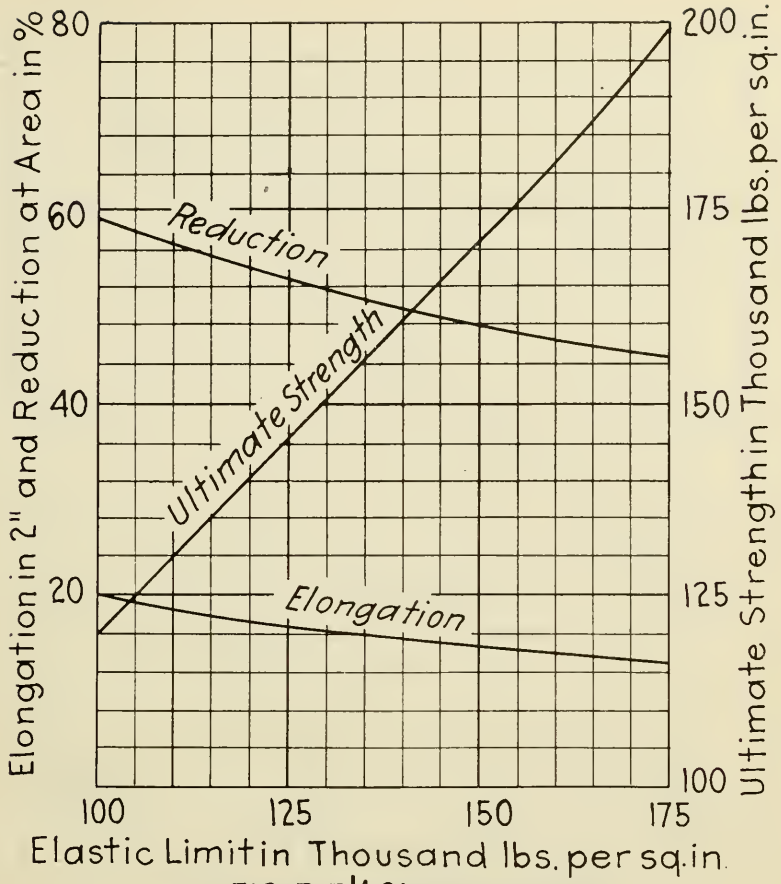


FIG. 3. 3½% NICKEL

Mr. Cutter: I got that quotation from an authoritative source, and I know that their prices vary somewhat. I happened to get that from a large steel company that is paying that much.

Member: Tool steel makers pay a high price; some steel companies are also paying very low prices, and some of them pay very high, so these figures it is necessary to know what the prices are, what the basis is.

Mr. Cutter: As I said in my paper, the method may be applied to the factor applying in any particular case. The charts were shown for the purposes of illustration, and I don't intend they shall be taken as absolutely arbitrary, absolute facts.

Member: The charts ought to show the actual cost on which you based your alloys. Otherwise they are very, very misleading, because without that knowledge no one knows what the prices were that you used, and they are very misleading in that way, because a concern that is using a low priced alloy would be mislead.

Mr. Cutter: I don't thnk they will be misleading at all, because the paper and the purpose of it is stated plainly, sir, and I have used

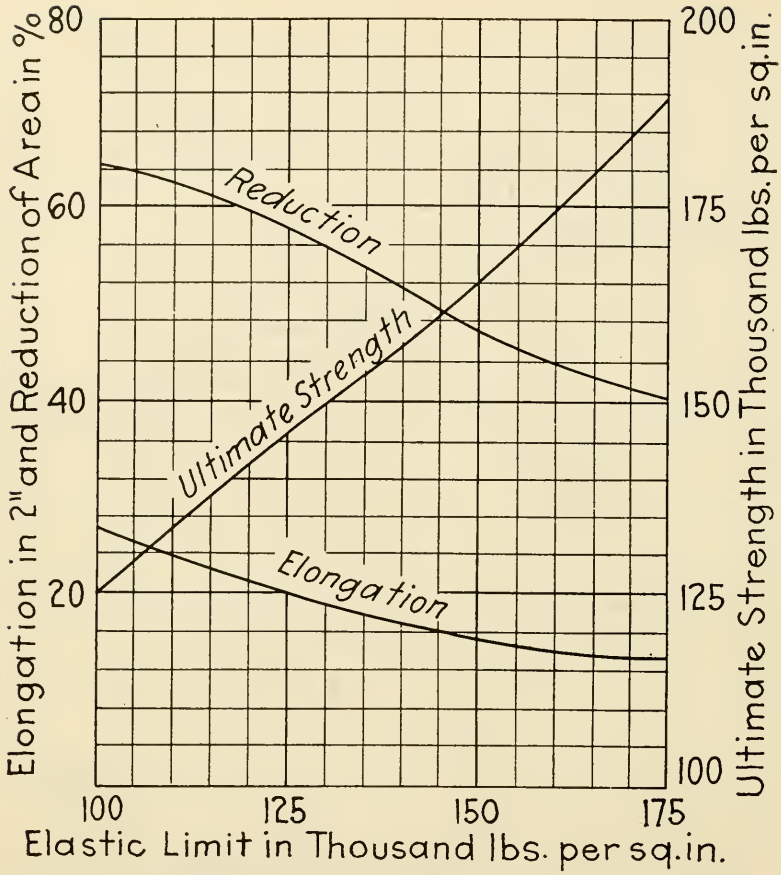


FIG. 4. CHROME VANADIUM

to the best of my knowledge the market quotations today, and that ought to be sufficient I think.

Member: As I say, I inquired as to what quotations you used, the maximum or the minimum, and the point is, which do you use?

Dr. Johnson: I would like to ask a question of Mr. Cutter. Is there any objection in sending in this paper for publication to incorporating the prices of the various elements on which these relative efficiencies of different steels are based?

Mr. Cutter: There is absolutely no objection to that, I think.

Chairman: Then you will have it so prepared for publication.

Member: I would say the paper or the charts are very misleading unless the prices of the alloys are given.

Dr. Johnson: The thought I have in asking this question, is that I understand Mr. Cutter in his prices based them on quotations he found in the leading journals. In that event his prices would certainly be high. I don't know of any quotation in the leading journal but what is higher than you can actually buy it for if you secured it in quantities, so if he has done anything he has rather been modest in his statement of the merits.

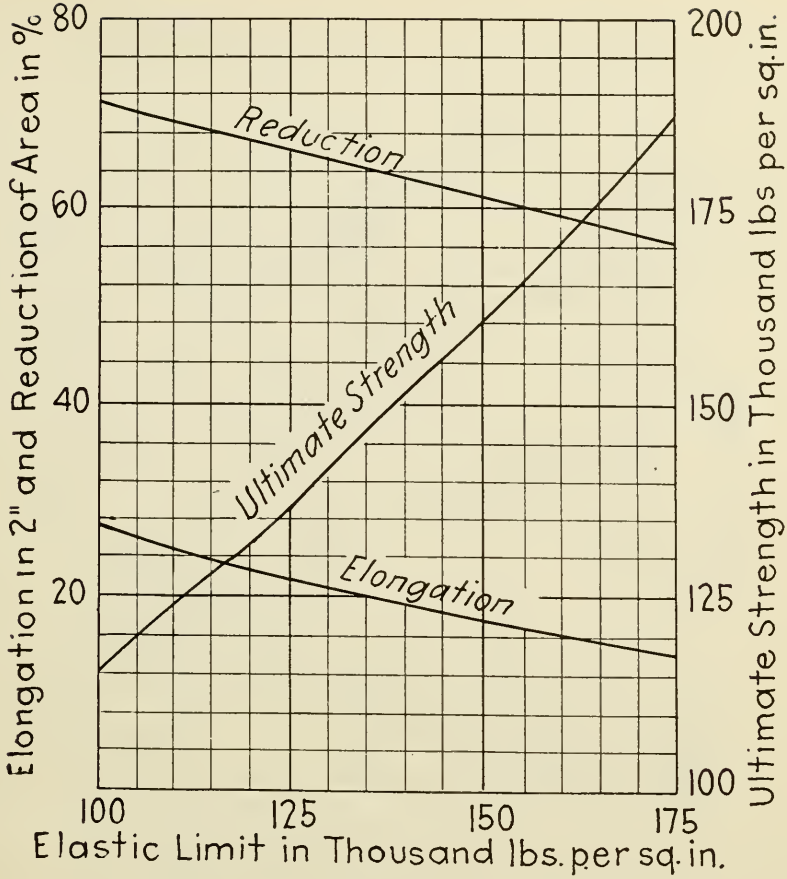


FIG. 5. CHROME MOLYBDENUM

Mr. Cutter: Thank you, Dr. Johnson. I think that the only process which I could follow was to take something which would be more or less standard. I might be able to buy vanadium or molybdenum at a very different price from some of my friends here, and the quotations applying to any individual would not be fair. I therefore took quotations that were as nearly standard as they can be made, as gotten from the leading journals, and it is understood perfectly from my paper I believe that these figures are not meant to be an absolute scale. The quotations were not secured for that purpose. And in any event it is interesting enough for you to investigate this method for yourselves and apply it to your own set of physical tests on the various steels and to your own quotations, and obtain your own results, and I am more than pleased that is the whole purpose of my paper, and if anyone thinks that some of these charts may be misleading, I will be very glad to individually go into them and show them the whole of my data from which the curves were plotted, and if it is thought by the committee that the actual market quotations which I used in developing these charts should be published with the paper, I will be very glad to have that done, or, if it should be decided that the charts

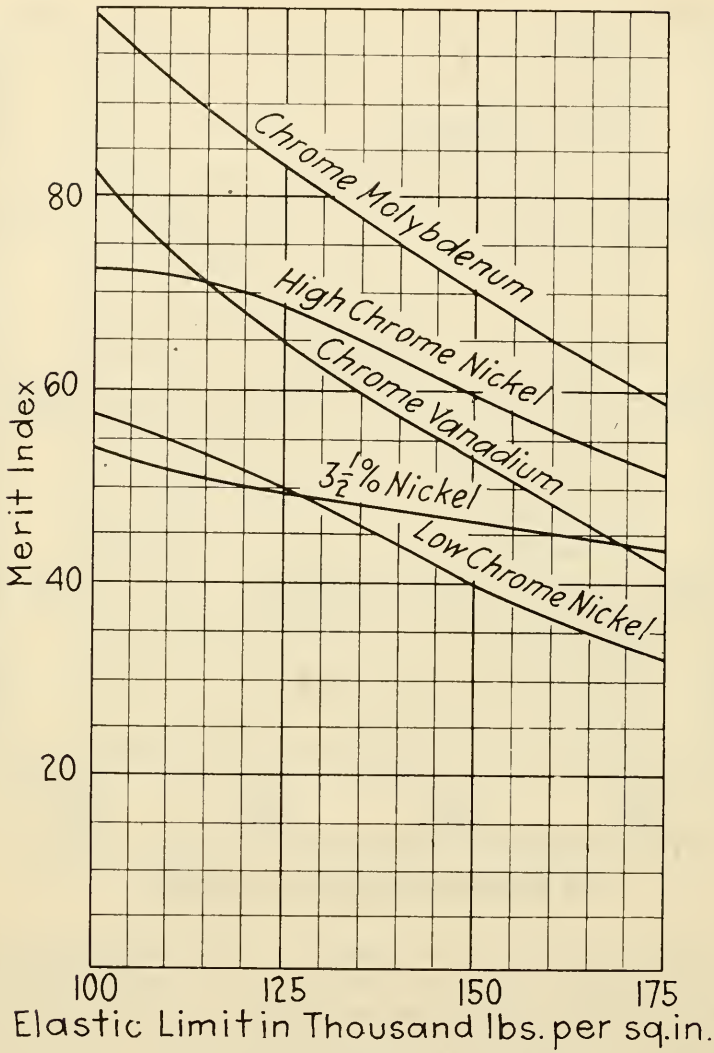


FIG. 6. MERIT INDEX

should not be published at all, it is absolutely immaterial to me. They are put in there for illustrative purposes, and my whole desire is to suggest this method of determining what I call the efficiency of the various combinations of alloys in steel, and if anyone will be interested enough to apply that method to their own data, the purpose that I had in writing the paper will be achieved.

Member: I would like to ask him if he has tried out at all any other merit index?

Mr. Cutter: Yes, I have experimented with a lot of them, but this one especially appeals to me, because it falls in line with the theory stated in the paper that the steel has merit in proportion to the ability of a unit

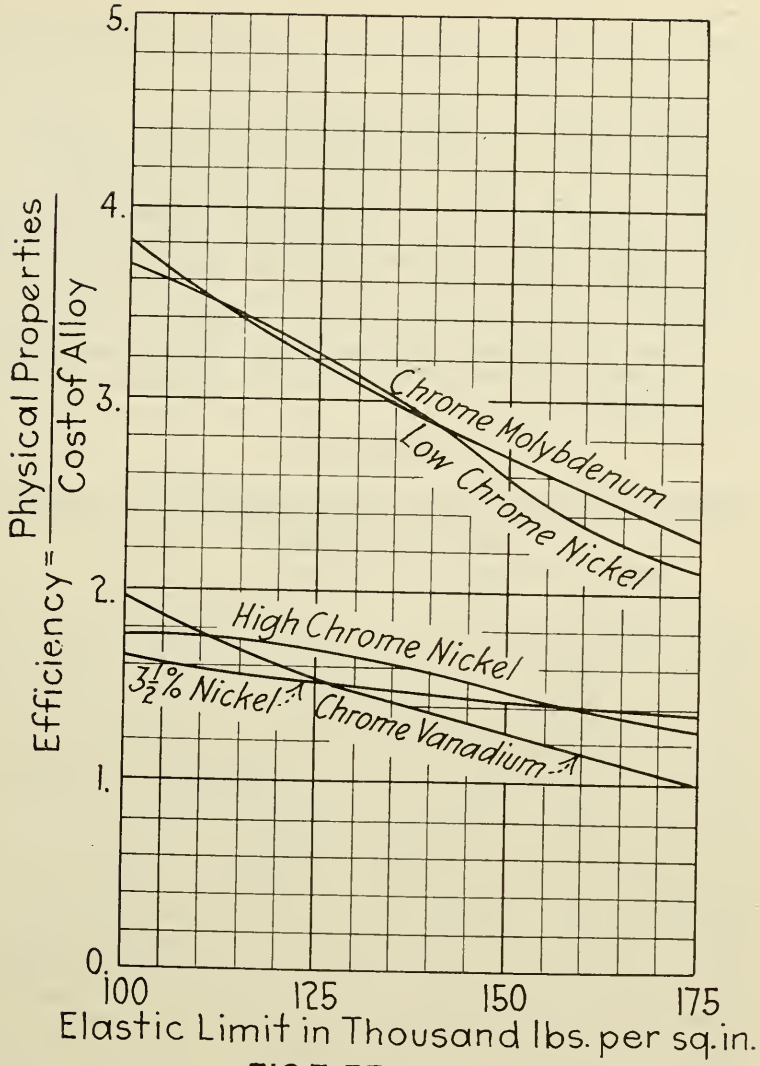


FIG. 7. EFFICIENCY

mass to withstand work done upon it, and if it hadn't been from that theory in the way it fits in with the merit index, I never would have written the paper.

Mr. D'Arcambal: May I ask Mr. Cutler, did you obtain these physical test results yourself or did you use different sources of data?

Mr. Cutter: There, again, I collected as many tests as I could, and I don't intend that the curves that I have shown shall be taken as a standard, either. The tests covered a wide range as to the size of section quenched and the source from which they came, and I tried my best to get something that would be an average result, from the S. A. E. and several other organizations, and averaged them up and I don't want to get into any discussion of them. My honest opinion is that they are very

representative of sections somewhat larger than the ordinary testing section. These are about one inch, some a little larger and some a little smaller.

Chairman: It is evident that the purpose of the paper was to describe a method of application rather than to establish a standard. Now our time is short, we have one more minute for discussion.

Dr. Johnson: If someone else has a question all right; if not, I would like to ask if Mr. Cutter knows about the approximate amount of molybdenum steel of this analysis that is being produced at the present time; that is, within the last few months what the approximate production in tonnage has been.

Mr. Cutter: I cannot speak accurately, Doctor, as to the tonnage that has been shipped. I have very accurate figures, I think, on the tonnage that has been ordered since the first of May, a little bit more than fifteen hundred tons placed on order.

THE ELECTRICAL HEAT TREATMENT OF STEEL

H. P. MacDonald*

(A Paper Presented at Philadelphia Convention)

In ordinary furnace practice it is customary to leave steel in the furnace through a definite soaking period, after it has been brought up to the required critical temperature. This necessarily results in deterioration of the metal through the action of the furnace gases causing scaling, decarbonization, and other injuries and also promotes crystal growth. It is necessary to have such a soaking period in a furnace where the material being heated receives its heat from outside sources, as a definite time is required for the transfer of heat by conduction from the outer to the inner portions of the material and furthermore, a large amount of work has to be done to affect the allotropic changes in the material which occur during the critical period and upon the completion of which the quality of the resultant material depends; in other words, not having any definite measure to tell when allotropic changes are completed, the operator using a furnace heating the material externally has to leave the material in the furnace long enough to insure these changes being effected, and as this time is variable with the section of the material and the heating properties of the furnace, the usual result is that to play safe, the operator leaves the material in the funace longer than is necessary.

In the heat treatment of steel by the electric method these difficulties are overcome. Referring to the accompanying cut of the apparatus used, it will be seen to consist of two sets of copper jaws (operated by pneumatic cylinders), connecting with which are the wires from the secondary of a transformer, designed to give heavy currents at low voltage. The upper contact remains stationary during the process, but can be adjusted to accommodate articles of varying length, the voltage being varied accordingly. The lower contact is free to move with the expansion or contraction of the specimen and to it is connected an indicating arm which travels over a dial to show the temperature of the specimen being heated. When the specimen is first put in the machine, the lower contacts are raised by means of a foot pedal shown in front of the cut, so that the indicator had

*Vice President, Snead & Company, Jersey City, N. J.

points to the room temperature. The piece is then placed inside the jaw and clamped.

This indicating mechanism is actuated by means of a pivot which is connected by worm and gearing to the drum on which the cable is wound which supports the upper contacts so that the application point of the pivot is varied with the length of the specimen and the indicator hand moves over equal intervals for the same temperature rises, regardless of the specimen length.

When the current is turned on by closing the switch, the material rapidly heats, due to its own internal resistance, and as it heats it expands until the critical point is reached. Here the expansion is either arrested or an actual contraction results, the material becoming noticeably colder and shortening in length. This contraction in the case of nickel steel often covers an interval corresponding to 150 degrees temperature.

While the current is on the operator watches this indicator and when this contraction ceases and the indicator begins to advance again showing an increase in temperature, the switch controlling the electric circuit is opened as are also the pneumatic operating jaws and the specimen is allowed to fall directly into the quenching bath below. It will be seen in this way not only is the critical point automatically shown up during the heat treatment, but also the operator is advised as to when the critical period has been passed and the article is in condition to be quenched,

The same apparatus is used for drawback, the article being then removed from the jaws and set aside to cool in the air.

The machine is at present being used for the heat treatment of nickel steel tubing for automobile propeller shafts manufactured by Snead & Company and in the case of tubing the quench can be affected by allowing the quenching compound to flow through the tube thereby quenching it in the machine and avoiding the necessity of a deep tank to contain the quenching bath in the case of long specimens. This apparatus is useful only with material having a constant cross-sectional area and through its use internal defects in the material can often be discovered. This feature is particularly valuable in the case of tubing, as thin spots in the center of the tube can be located by the increased temperature, spots which otherwise would never be discovered and might result in dangerously weakening the tube.

The accompanying charts show some of the phenomena observed during this process. These charts represent the average workings of ten specimens of steel having 3.45 nickel and .36 carbon. Chart #1 shows time and total B. T. U.'s and time and time and temperature, and on the latter, the reversal of the curves in the critical range can be readily seen. The dotted line represents the workings on a second heating after the first quenching operation and the critical point is at a noticeably lower temperature. It should also be noted how rapidly the temperature increases after the critical point has been passed showing how readily steel can be overheated.

The B. T. U. curve shows that while 142 heat units are required to raise the temperature to the critical point, 61 more must be added to complete the internal transformations necessary before quenching, in other words, thirty percent of the total heat units required are necessary to work allotropic changes which increase the latent heat without increasing the temperature of the article.

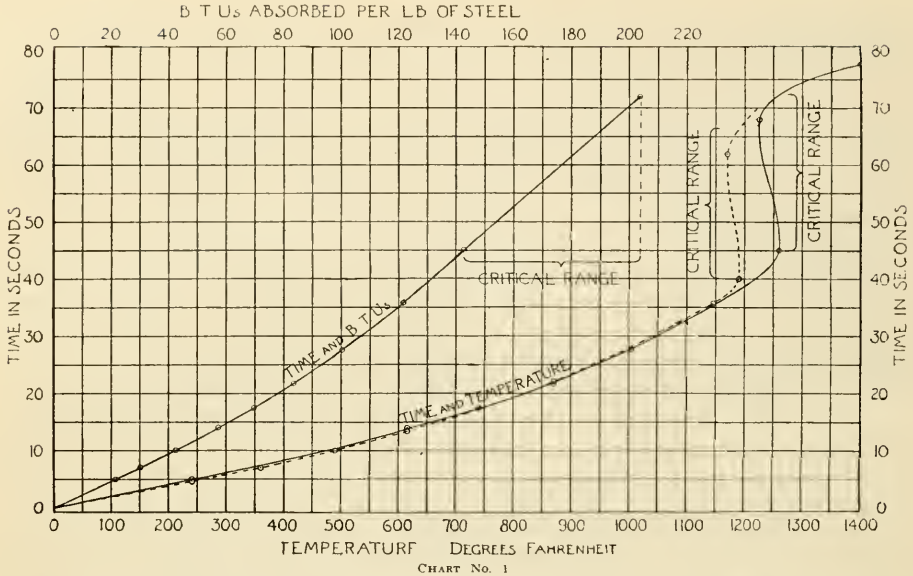


Chart No. 1

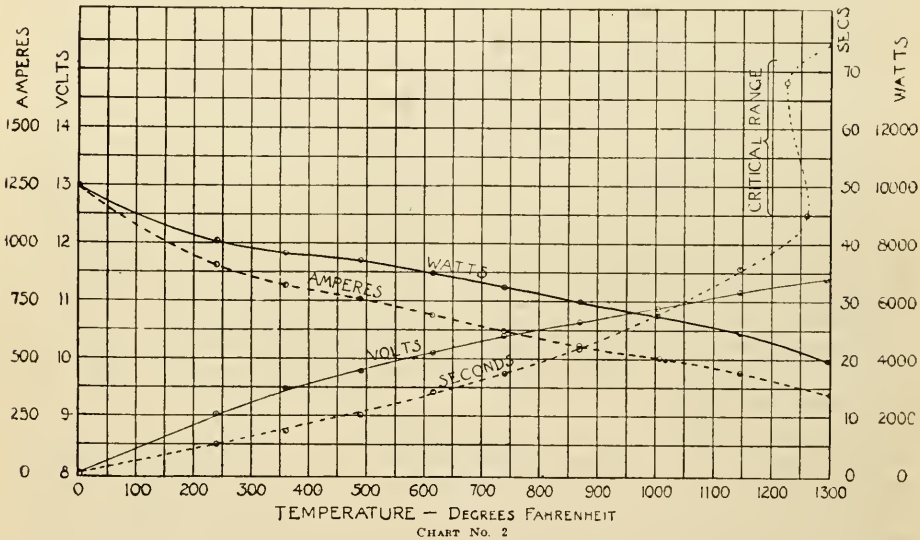
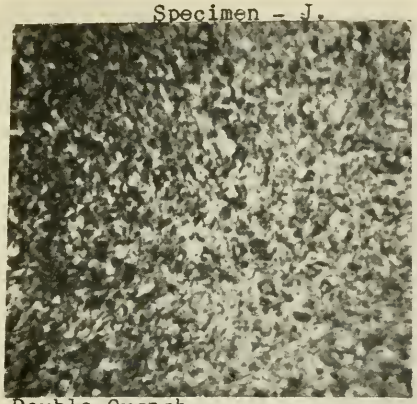


Chart No. 2

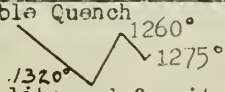
Chart #2 shows watts, volts and amperes, as well as time and temperature. Both these diagrams are based on runs where the heating was intentionally slowed down to enable the operation to be more readily observed, thirty to forty seconds in the average time required to heat a 16′ tube. Three volts to a foot length of material that is of the ordinary steels, are required and a current density of 8,000 ampers per square inch. Solid bar stock takes about .06 of a kilowatt hour per pound of material heated to its critical point.

A series of experiments were made to show if there were any higher qualities obtained the steel of this character through a double quench and the accompanying micophotographs and table #1 show the results

Specimen - J.



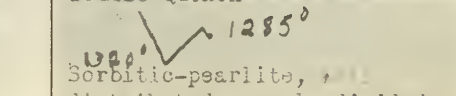
Double Quench



Pearlite and ferrite. Well distributed - evenly divided.
Ult.Str. - 229,250 lbs.sq.in.
Yield Pt.- 210,350 lbs.sq.in.
Elongation in 2" - 10.5%
Reduction in area - 53.5%
Fracture - semi-cup, silky.
Magnification - 500 dia.

Specimen - K

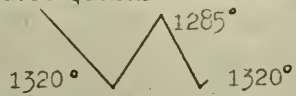
Double Quench



Sorbitic-pearlite, [illegible] distributed, evenly divided
Ten. Str. - 238,800 lbs.sq.in
Yield Pt. - 206.200 " " "
Elongation in 2" - 9.75%
Reduction of area - 53.0%
Fracture - full cup, silky
Magnification - [illegible]00 dia.

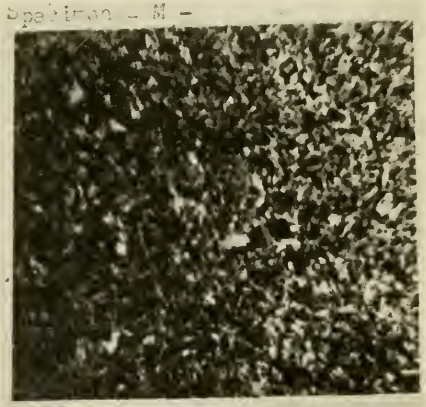
Specimen - L

Double Quench

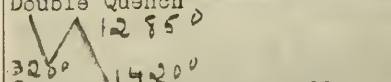


Pearlite and ferrite. Shows tendency to segregation.
Ult. Str. - 238,900 lbs.sq.in.
Yield Pt. - 200,125 lbs.sq.in
Elongation in 2" - 11.5%
Reduction of area - 52.1%
Fracture - semi-cup, silky
Magnification - 500 dia.

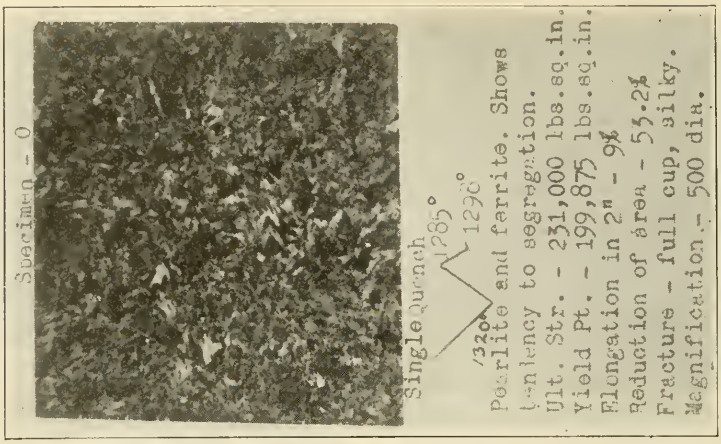
Specimen - M -



Double Quench



Sorbitic-pearlite, small amount of slag
Ten.Str. - 231,900 lbs.sq.in
Yield Pt. - 203,050 lbs.sq.in
Elongation in 2" - 9%
Reduction of area - 53.65%
Fracture - full cup, silky
Magnification - 500 dia.



of this and the structures obtained.

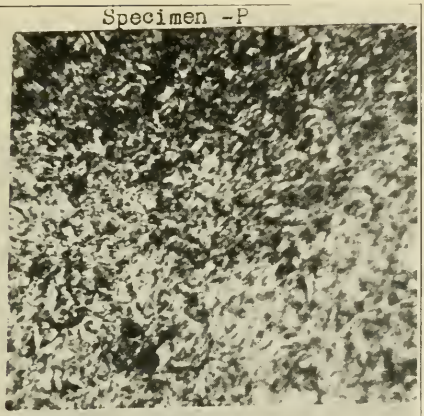
The zig-zag lines below each microphoto show the time at which the specimen was quenched, i.e., the left hand line represents the advance in heating the material, the center line the contraction during the critical period, and the right hand line, the expansion occuring before quenching. It will be seen that excellent results are obtained by quenching as soon as this expansion begins, and also a tendency to segregation if the temperature is materially increased. This material was cold rolled bar stock 3.48% Nickel and .38% Carbon and was tested in the original sizes.

PROPERTIES OF 3½ PER CENT NICKEL STEEL

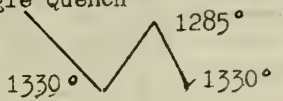
Specimen*	J	K	L	M	O	P
Nickel, per cent	3.46	3.47	3.48	3.46	3.48	3.48
Carbon, per cent	0.39	0.39	0.39	0.39	0.39	0.38
Structure	Sorbitic-pearlite Well distributed evenly divided	Sorbitic-pearlite Well distributed evenly divided	Sorbitic-pearlite	Sorbitic-pearlite	Sorbitic-pearlite	Sorbitic-pearlite
Amount of slag	Small	Small	Small	Small	Small	Small
Ultimate strength, lb. per sq. in.	229,250	238,800	238,900	231,900	231,000	233,550
Yield point, lb. per sq. in.	210,350	206,200	200,125	203,050	199,875	197,600
Elongation in 2 in., per cent	10.50	9.75	11.50	9.00	9.00	10.00
Reduction of area, per cent	53.50	53.00	52.10	53.65	53,20	54.00
Fracture	Semi-cup, silky	Full cup, silky	Semi-cup, silky	Full cup, silky	Full cup, silky	Full silky
Treatment	Double	Double	Double	Double	Single	Single
Drawing temperature, deg. fahr.	630	630	630	630	630	630

*Letters refer to photomicrographs.

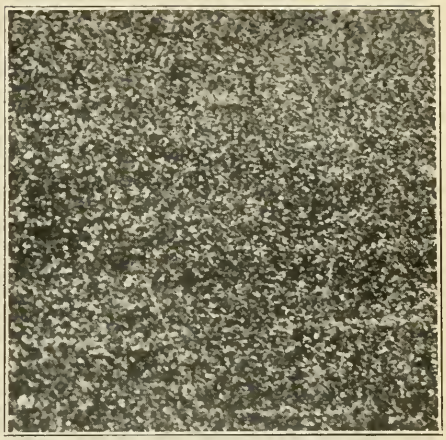
Specimen -P



Single Quench



Pearlite and ferrite. Shows tendency to segregation.
Ult. Str.- 233,550 lbs.sq.in.
Yield Pt.- 197,600 lbs.sq.in.
Elongation in 2" - 10%
Reduction of area - 54%
Fracture - full cup, silky
Magnification - 500 dia.



Steel Tube from Drive Shaft
Magnification, 100 dia.
Single Quench and drawn back at 800° F.

Table #2 gives another set of tests which clearly show the necessity for allowing sufficient time for the complete allotropic changes to take place and that when once this has been accomplished, no further gain can be made by prolonging the heat.

Specimen	Elongation in 2 in., per cent	Reduction in Area, per cent	Yield Point, lb. per sq. in.	Ultimate Strength, lb. per sq. in.	Period of Quenching
3C	9.75	41.90	126,550	181,550	After being in critical period 12 sec.
3H	9.00	50.90	154,150	175,500	After being in critical period 15 sec.
3K	11.75	43.45	140,400	175,400	After being in critical period 10 sec.
3L	9.50	52.20	202,400	227,300	After being in critical period 29 sec.
3D	10.00	52.60	201,350	223,350	Just through critical period.
3E	10.00	56.70	198,800	216,150	120 deg. fahr. above the critical period.
3F	11.50	58.30	193,300	212,250	240 deg. fahr. above the critical period.

Table #3 gives the same results for double quench.

Specimen	Elongation in 2 in., per cent	Reduction in Area, per cent	Yield Point, lb. per sq. in.	Ultimate Strength, lb. per sq. in.	Period of Quenching
3A	19.75	56.25	83,050	117,650	After being in critical period 15 sec.
3G	11.50	56.90	202.300	216,150	Just through the critical period.
3J	10.10	53.85	203,600	214,250	95 deg. fahr. below the critical period.

Table #4 shows what can be accomplished by working to a lower drawback temperature and in this case the high reduction of area combined with the ultimate strength are noteworthy.

		3.5% Nickel	.36% carbon
Material	Steel		
Laboratory Test Number	7234	7235	7237
Mark on Test Piece	12	12	13
Shape of Test Piece	Rod		
Guaged length, in inches	2	2	2
Diameter, in inches	0.371	0.371	0.371
Area in square inches	0.1081	0.1081	0.1081
Diameter at fracture	0.289	0.289	0.283
Area in square inches	0.0656	0.0656	0.0629
Elongation in 2 inches	0.23	0.2'	0.20
Percent Elongation	11.5	10.5	10.0
Percent Reduction of area	39.4	39.4	41.8
Yield point, in pounds	20000	20500	20500
Maximum load, in pounds	28920	28830	28840
Yield pound, lbs. per square inch	184900	184900	189600
Ultimate Strength, lbs. per sq. inch	267300	266500	266500

A number of tests have been made by the Company and others on their own product. Noteworthy among these are tests made by the H. H. Franklin Company. This is on a shaft using tubing of 3½% nickel steel, .25-.35 carbon, 1¼″ diameter—16 gauge, given a single quench and drawn back at 700 degrees. These shafts were 45″ long.

No. 1

Torsional moment at elastic limit	14200	inch pounds.
Shearing stress at elastic limit	109000	pounds per square inch.
Torsional moment at max. strength	15700	inch pounds
Shearing stress at max. strength	120500	pounds per square inch.
Angle of torsion at elastic limit	48	degrees
Angle of torsion at max. strength	112	degrees

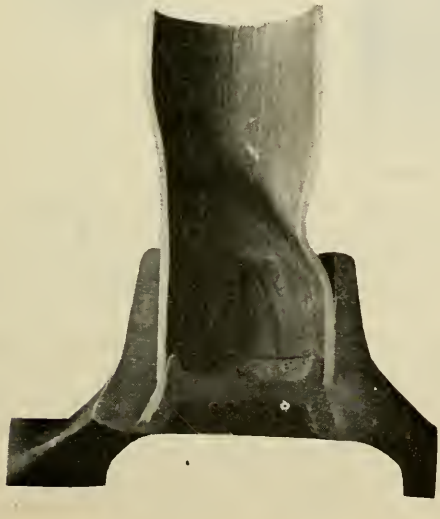
No. 2

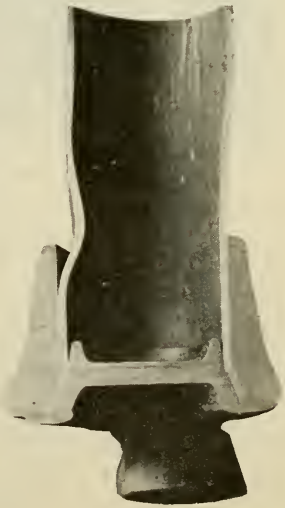
Torsional moment at elastic limit	14700 inch pounds
Shearing stress at elastic limit	113000 pounds per square inch.
Torsional moment at max. strength	15750 inch pounds
Shearing stress at max. strength	121000 pounds per square inch.
Angle of torsion at elastic limit	50 degrees
Angle of torsion at max. strength	120 degrees

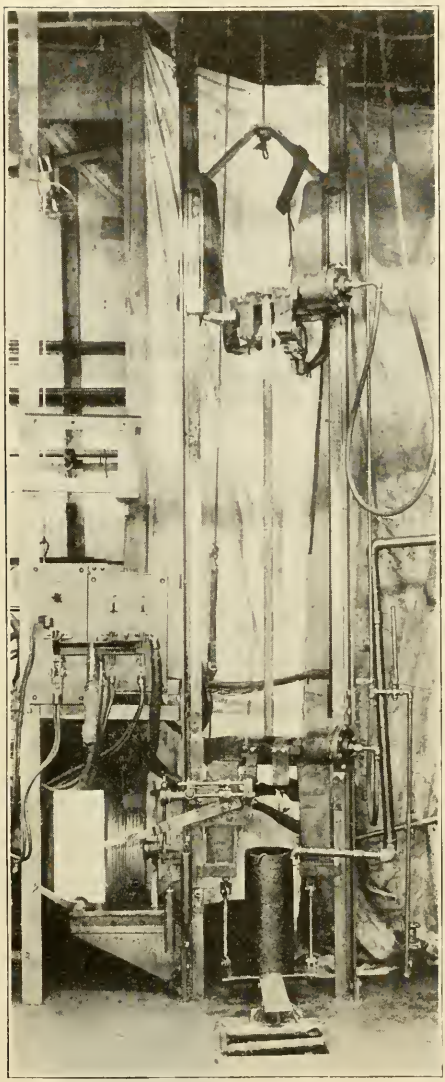
Tests have shown that for this light gauge tubing, the torsional strength per square inch is about .6 of the tensile strength. These results are typical of what has been obtained by the Company in its regular product, i.e., tubing with the dropped forge steel spiders attached by the use of a hexagonal wedge expanding the tube into a hole in the spider as shown by the accompanying photograph. This method develops the full torsional strength of the tubing without depending on welds to take up the torsional strains. The accompanying micophotograph shows the section of such a tube enlarged 100 diameters. See page 203.

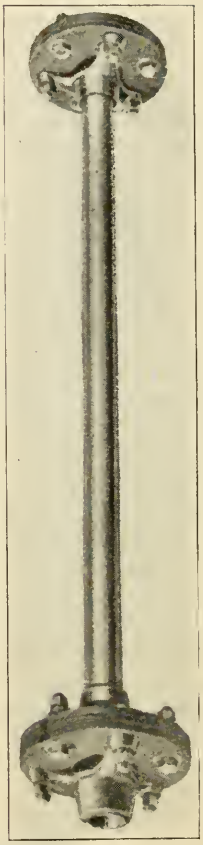
The advantage of this method of heat treatment may be summarized as follows: The rapidity of the process, the heating before quenching usually being accomplished in less than one minute, the absence of scale, decarbonization and crystal growth due to the rapidity of the process, the indication of the temperature and critical point of the material by the physical changes in material itself, absence of refractories, (the only parts of the machine needing replacement being the copper contracts, which gradually wear out) the freedom from warping and the low cost of operation when current can be obtained at reasonable prices. This latter is due to the fact that virtually the entire energy is used in useful work, the process taking place so rapidly that comparatively little heat is lost through radiation.

Its limitations are those of requirements of a constant section for the article being heated (this section need only have a constant area, the shape may vary) and the fact that when alternating current is used, the element of reactance of the circuit comes in to such an extent that greater









Machine used for Electrical Heat Treatment

voltage is required at the transformer to overcome it. Where direct current is available no such element of reactance comes in and the only requirement would be the proper initial voltage and amperage of current available. The equipment now in use is limited to sections of about 1¼ square inches.

The process was developed during the late war in connection with the execution of an order for Cossack lances made from steel tubing, the specifications requiring an elastic limit of about 83,000 lbs. As time went on the Company made use of it for the heat treatment of steel tubing for the Italian Royal Flying Corp. for use in aeroplane and dirigibles, some of these sections of tubing were over 20 ft. long and very light gage, nevertheless they were brought out practically straight after quenching.

Later on when this country got into the war we heat treated tubing used for the landing chasses of the Handley Page aeroplanes made at Elizabeth, New Jersey, and were working with the Dayton Wright Company in connection with heat treating their airplane axles at the time of the armistice. On sample shafts furnished by us composed of 3½% nickel steel, their tests showed an elastic limit of 220,500 lbs. and an ultimate strength of 246,000 lbs. with 6½% elongation in 2″, more than satisfying the government specifications. It is important to note in this connection that tubing and shafting can be heat treated to high tensile strength without serious warping, this appears to be due to the fact that the material is heated simultaneously throughout its section rather than having the heat soak in from the outside.

It is also interesting to note that the critical periods appear to occur at a lower temperature than in ordinary furnace work and that the physical results are much higher than those ordinarily obtained by the same material. The former is possibly due to some electrolytic action in the steel, due to the passage of current and the latter to the complete control incidental to the process and possibly to the more thorough allotropic transformations.

DISCUSSION OF MR. MACDONALD'S PAPER

Chairman: To me this is something of an innovation in the method of steel treating. Perhaps it is not so to some of you, but I imagine it is a very interesting subject and will bring forth some discussion. The floor is yours now to fire all the questions you dare to at Mr. Macdonald.

Mr. Rockwell: I will ask you if you found any difference in your warpage or expansion by dropping down just before the recalescence before quenching? That is, your pointer shows expansion and then contraction and then at the starting to turn for expansion again you shut the heat off. Supposing you follow down until just the point before you start to expand again. If you should quench in there would you find any difference in the structure, in the physical properties and the warpage?

Mr. McDonald: We found a very material difference there. If you don't get over that kink, if the points begin to show an increase in temperature again, the physical values fall off very materially.

Mr. Rockwell: I mean after your pointer has gone over, started to expand on the heating,—you heat up, you expand, as you go through your critical range you contract, then you start to expand again,—your change has been made, then you cut the temperature off; supposing you let it fall down just before the point she starts to expand again?

Mr. MacDonald: That would go down too low, I believe to get it.

Mr. Rockwell: You are still above the critical range.

Mr. MacDonald: I have not tried that.

Mr. Rockwell: I have tried it out in a small way on small tools by heating in an electric furnace and supporting my work on silica plates and I noticed that function as read directly off on an Ames Dial, and I got some remarkable results that way. I cut the warpage way down and stopped the scaling and stopped grain growth. My attempts were very successful.

Mr. Marshall: May I ask if you applied that method at all to any higher carbon steels what would be the effect?

Mr. MacDonald: We haven't tried it out on any higher carbon steels.

Mr. Marshall: The tool steels we always handle with care, and the rapid heating would seem a drastic treatment.

Mr. MacDonald: It seems drastic, but when you come to look at it you are heating the material simultaneously through all the section. If you put the material in a furnace that is very hot the outside of the material is heated first. Therefore you get very heavy internal stresses, but if you raise the temperature uniformly throughout the mass, simultaneously, you don't get that condition. I think you would get pretty much the same thing in 3.5 per cent nickel steel that you would with the other. Well, I recently heat treated a rear axle spindle for a full floating axle for an auto truck. That was quite a high carbon steel, I think about .50 carbon, and we had no difficulty there at all. That had splined ends but the spline was so designed that it had practically the same area as the rest of the section, and we had no difficulty.

Mr. Hurley: I would like to ask Mr. Macdonald how you keep the ends of a propeller shaft as hard as the central section. I should think the clamps would draw away a certain amount of heat.

Mr. Macdonald: We don't. The ends about an inch and one-half on each end, are not heated, and we cut them to waste. That is one reason why we use the heat treatment in long lengths. We cut them in 16 feet lengths and cut them to average up only 14.

Mr. Decker: Is there any reason why you couldn't make that to handle stock an inch and a quarter?

Mr. MacDonald: There is no reason except the electric current available. We are drawing on the city power there and we are taking about all we can have. It is a pretty heavy kink on the load you know to throw that right across the line, and we can only use single phase; that means we are only drawing off one side of a two phase circuit. A direct current is the ideal way to handle a thing of course.

Mr. Rockwell: Could you use that in a continuous process for heat treatment of wire?

Mr. MacDonald: I don't see why not. Of course it is different with the continuous process; you wouldn't be able to get the measurements like we do now. It has been used. The same method has been used for annealing wire where you simply heat it up to a definite temperature and of course where you don't have to work quite so closely I don't imagine you would need (interrupted).

Mr. Rockwell: You could first establish your temperature by your voltage, by your dial, and hold it there.

Mr. Ryan: Has that process been used very extensively for the heating of rivets?

Mr. MacDonald: There is an electric process used quite extensively for rivet heating, but that is a different proposition. What we have here is no temperature measurement other than by eye, and it is largely a matter of contact resistances as well as internal resistance in heating there.

Mr. Hurley: Mr. MacDonald said that on the quenching heat it took about forty seconds to effect the necessary changes before you quenched it. Does it take longer than that on the draw?

Mr. MacDonald: O, no, the draw takes very much less time, probably only twelve seconds. You see you have a good part of the time in the critical period when you are quenching. Those moving pictures give you a very good idea of the time it takes. I think they are run off a little bit more rapidly than the actual process.

HEAT TREATMENT OF TRUCK AXLES

Harry E. Hemstreet*

(A Paper Presented at Philadelphia Convention)

Heavy worm drive Motor Truck Axles are unit parts of various kinds of steel assembled together as a load carrying member of the truck, and as such must be capable to deflect without deformation. The Designing Engineers speaking of them claims actual stresses on parts in service is unknown, or the finest scientific calculations, mathematically figured from beam stresses of material, are virtually hopeless in determining factors of safety accurate for unit parts, only the acid test of actual road performance being reliable where distructive forces are constantly at work on the material of construction when in service. These unit parts are subject to all known stresses of material, and as a factor of safety in longevity of life for serviceableness must receive careful applied steel heat treatment.

All material before entering into Axle manufacture has the chemical analysis taken, sample pieces of each individual heat of steel is heat treated for laboratory test purposes, where pieces are examined under the miscroscope for impurities and the nature of its physical structure, others pulled apart, torsion and transverse tested.

The Metallurgist in axle manufacture has cast steel annealed, drop forged parts case hardened and triple heat treated, parts machined from screw stock, case hardened, triple heat treated, drop forge, yokes, knuckles, side axles, break levers, steering levers, connection rods and connecting rod clevis, which are all normalized, hardened by quenching and tempered. All axle parts receive a 100 per cent hardness test, either by Brinell hardness test or Scleroscope method, which necessitates having a good heat treating equipment and heat treating all parts by a heat treating card which specifies heat temperatures according to the chemical analysis of the heat number of the steel used in manufacture of the parts.

Only such parts which are hardened by quenching will be taken up in this article, other heat treating methods used being covered by other papers.

The steel on arriving in the forge department is heated to be forged into the various shapes, such heating is of great importance on the physical structure, qualities of the part after final heat treatment, also regulates the time and temperature for final heat treatment. Too great a care can not be exercised in this department in heating, for if the structure of the steel has a fine grain structure at the end of the last forging operation, steel not overheated previous, then the hardening and tempering operation on the final treatment is sufficient for a good commercial product.

It seldom pays to eliminate the normalizing and seldom is done for the parts by the use of this method are all made uniform in physical structure first, such uniformity will be the test results on all parts, after hardening and tempering with accurate temperatures in heating.

The heating temperature generally used in forging is between 2,000° F. and 2,100° F. to make the steel plastic in hammering it, while such work generally stops at around 1,500° F. and is allowed to air cool. Temperature control of the forge furnaces with plenty of furnace floor space for heating, so that the specified working temperature has time to heat the metal plastic clean to the core, is the ideal conditions of forging steel. The forgings where heated at the lowest possible temperature will have a

*Sheldon Spring & Axle Co., Wilkes-Barre, Pa.

smooth and cleaner looking surface, less change of ferrite segregation spots, and be more uniform for length. The old system some used with the lack of furnace capacity was forcing the heat applied to make adequate production, which caused the steel to become nearly liquid or even so that it dripped when being moved to the hammer. Such high temperature generally causes a heavy scale which is not easily removed from the die, thereby becoming hammered in the steel; these forgings, alas, have a very coarse grain structure which requires more time at a little higher temperature in normalizing than ordinary. Overheated forgings look anything but mechanical for mechanical workmanship. Some parts require from three to five heats in forging and each heat should be carefully controlled so that the finished product will show neatness of workmanship, showing up the lines of gracefulness in design of the part. It is only human nature for men working piece work if their furnace heating capacity is not great enough for continual working heat to increase the temperature a little more than necessary for forging the steel part, which in most cases where allowed or done there occurs trouble in the machining of the steel even after heat treatment for the coarse crystalline structure so caused needs special attention, other than the regular methods to thoroughly refine the crystalline structure of the steel to non-crystalline when once overheated. The best method at all times is making sure of not having any more grain growth than is absolutely necessary for drop forged parts, the same will lessen the burden in final heat treatment and machining. There is no question of a doubt but the best remedy for controlling drop forge heats is the applying of good common sense from test results, and other mechanical operation where overheating has caused trouble before. The front axle yoke which is hammered into an I-beam type of construction, forging a pad near the ends to fasten the spring to, and shaping the clevis ends for inserting the steering knuckle receives six different heats at least in forging the last heat taken being a normalizing heat when the drop, if specified, is put in the bed of the axle and alignment in straightening is done.

The yokes are generally forged from a straight 30 to 40 per cent carbon steel with heat treatment adjusted to a tensile strength of 85,000 to 95,000 lbs. per square inch, elastic limit of 50,000 lbs. per square inch, elongation, 22 per cent, 2 inch, reduction of area 45 per cent, which gives good ductility for machining. The yokes in heating to harden are loaded in an under-fired combustion chamber furnace in a layer with the top side of the axle up, which gives the spring pads ample heating contact with the heat, as this is the thicket part of the yoke to heat. The amount of weight and diameter of the thickest part regulates the time of heating, which, as a rule, comes close to one hour, 20 minutes, for 600 lbs. at an approximate thickness of 1¼″ at thickest part, temperature 1,550° F. On being quenched in water, they are lowered in very quickly, being agitated till the steel drops below the critical range then left at rest; separate till about 200° F., when the part is removed and loaded on trucks for tempering. The parts are held at the tempering temperature one hour after maximum heat has been reached then allowed to air cool, Brinell hardness being 217 to 228.

The rear side axles, steering-knuckles, steering and break levers require steel, having a higher elastic limit, so the side axle is made of a 3½% nickel steel, 30 to 40 per cent carbon; other parts 1½% nickel steel. Side axles require a careful heating for physical properties, sufficient to carry load while revolving and withstand the impact road shocks, torsion

and transverse stresses. The drive shafts are first normalized, air cooled till cold, then reheated from 1,450° to 1,475° F., being given ample time to heat, then the heavy part at the hub shoulder, which is about 1/3 more in diameter than the differential end of the axle shaft without causing grain growth on the smaller end while the larger is heating. These side axles are water quenched in a temperature regulated bath, agitated while cooling below the range then being removed while about 200° F., immediately loaded in the oven for tempering, being held at the maximum tempering temperature 1½ hours in time. Steering knuckles, brake levers and steering levers are quenched in oil at 1,500° F. tempered for the same Brinell hardness as the front yokes.

One of the main factors in heat treating steel is keeping the parts in alignment so that they do not have to be straightened or twisted in order to true them up before machining. Skill in quenching alone regulates the amount of such work, providing the heating has been done uniform. The quenching horizontal of parts must be done quickly, raising the part upward again right after emersing in the quenching medium and lowering till the part is cooled below the critical range.

Where parts do have to be straightened or twisted the steel should first be heated to at least 400° F., then it will still be classed as cold working of steel; the effects though, will not be so severe as actual bending cold. Better to straighten any part which may be out of alignment when the material is removed from the tempering furnace, as then the parts are thoroughly heated through. Such work upon the material while heated shows no defects under microscopic examination.

Factories having a large enough capacity for the installing of a conveying type furnace, are finding the parts heat treated by their use, of excellent quality with very little variation in hardness test and physical test. These conveying type furnaces seem to be the ideal way to heat treat axle parts, as the heating temperature rise is gradually applied till the maximum temperature desired is attained, when the parts are allotted a certain time at full temperature, then progressively passed out of the furnace into the quenching bath, conveyed through the quenching medium upon a tempering conveying furnace which also regulates the time of tempering temperature for an absolute positive heating through to the center, which gives a ductile steel for machining operation of uniform strength.

Mechanical contrivances in heat treatment are becoming universally used now, which corrects a great many evils of defective heat treatment by regulating necessary time, mass and temperature.

NOTICE

CHANGE OF HEADQUARTERS

Beginning November 20th, 1920, address all correspondence to

AMERICAN SOCIETY FOR STEEL TREATING

4600 Prospect Avenue
CLEVELAND, OHIO

CHAPTER NOTES

CHICAGO CHAPTER

The Chicago Chapter held the November meeting in the rooms of the Western Society of Engineers at 7:30, Wednesday evening, November 17th. Mr. Robert B. Kerr, foreman, heat treating department, John Deere Harvester Company, East Moline, Ill., presented a paper on the "Hardening of Hammer Die Blocks."

Mr. Kerr has had years of experience in this work, and presented in a very interesting and instructive manner the methods he had employed with such satisfactory results. The subject was of great interest to the membership present, and brought forth some of the most interesting discussions that the Chicago Chapter has ever experienced.

The next meeting of the chapter will be on December 14th, when Mr. Howard Stagg, assistant manager, Halcomb Steel Company, Syracuse, N. Y., and a member of the board of directors of the National Society, will be present at a dinner meeting and present a paper.

In the same letter, containing the announcement of Mr. Kerr's meeting, was enclosed an announcement relative to the establishment of educational courses by the Educational Committee of the Chicago Chapter, of which Mr. T. E. Barker is chairman. The announcement follows:

Announcement

The Armour Institute and the Lewis Institute, with the co-operation of the American Society for Steel Treating, will soon open evening courses on forging and heat treatment of steel.

These courses have been especially planned by our Educational Committee for the benefit of the practical workers, and those who wish to qualify for such work.

The courses will embrace the following phases of the work:

"The Pyrometer."

"The Microscope."

"Forging (showing effects of proper and improper heats and conditions)."

"Annealing."

"Alloy Steels (dealing with the effects of different alloys and treatments upon the physical characteristics of steel)."

"Hardening and Drawing of Tool Steel."

"Case Hardening."

Seven sub-committees, each composed of three of our members who are actively engaged in the metal working industries of our community, have each prepared one of the seven texts covering the seven phases above mentioned and will teach their subject by practical methods to these classes.

The members of the above mentioned committees have been actuated in this work purely by a desire to be of service. None will receive financial compensation for preparing these texts, lectures, and demonstrations. Wili you not, therefore, do your "bit" in the interests of our society and the schools, by giving this announcement as much publicity as is possible among those of our associates, either in or out of your plants, who you think might profit from the course?

Those interested should, for further particulars, address: Armour

Institute of Technology, Thirty-third and Armour avenue, or Lewis Insitute, Madison and Robey streets.

CLEVELAND CHAPTER

About 150 members of the society were present at the October meeting of the Cleveland Chapter held at the Cleveland Engineering Rooms, Statler Hotel. The Program Committee was very fortunate in obtaining as a speaker one of the very busy fellow members and one who has had wide experience in the manufacture of steel, Mr. Howard J. Stagg, assistant manager, Halcomb Steel Company, Syracuse, N. Y., who delivered a very capable paper. The discussion following the paper was very interesting and brought forth many valuable suggestions for solving various difficulties.

BUFFALO CHAPTER

Mr. Jos. V. Emmons, metallurgist, Cleveland Twist Drill Company and chairman of the Cleveland Chapter, presented a paper before the Buffalo Chapter on Monday evening, November 1st, on "The Heat Treatment of High Speed Steel." The meeting was held in the assembly room of the University Club and proved especially valuable to those who were in attendance.

INDIANAPOLIS CHAPTER

The October meeting of the Indnanapolis Chapter was addressed by Prof. Moore of the University of Illinois, who selected as his subject the "Fatigue of Metals." Prof. Moore's paper was illustrated by lantern slides, and was the result of extensive research work that he has conducted in the laboratories of the University of Illinois.

The meeting on November 5th was addressed by Mr. Charles M. Johnson, director of research department, Crucible Steel Company of America, Pittsburgh, Pa. Mr. Johnson told of his work in the development of a new steel and also assured the members that his article would be ready for publication in the transactions as soon as he had finished the preparation of some additional work.

The annual visit and inspection of the Indianapolis Chapter took place on Friday evening, November 19th, when President White and the National Secretary Eisenman were present. They were met by the Convention Committee of the Indianapolis Chapter and spent the day investigating Indianapolis as a possible location for the 1921 Convention and Exhibition.

DETROIT CHAPTER

About 150 were present at the October 27th meeting of the Detroit Chapter, when Dr. George W. Sargent of New York presented a paper on "Molybdenum Steels." Dr. Sargent showed the results of a number of tests that had been made with the use of molybdenum as the alloying element and also presented some interesting facts as to the method of mining molybdenum. President White and the National Secretary Eisenman were also present at the meeting and addressed the membership.

CINCINNATI CHAPTER

The November meeting of the Cincinnati Chapter was held at the Ohio Mechanics Institute on Friday, November 5th. The feature of the meeting was a report of the Philadelphia Convention by Dr. Hartzell of the Victor Safe & Lock Company, Mr. A. L. Meyers and Mr. Harold LeBlond of the R. K. LeBlond Machine Tool Company. The outline for the coming year was presented and discussed, as was also the advisability of holding the 1921 Convention and Exhibition in Cincinnati.

The second November meeting of the Cincinnati Chapter was addressed by President White and National Secretary W. H. Eisenman, at the Business Men's Club on Thursday evening, November 18th. These gentlemen spent the day in Cincinnati with the Convention Committee and the Secretary of the Chamber of Commerce, and investigated the city as to the advisability of its being able to accommodate the 1921 Convention.

MILWAUKEE CHAPTER

The November meeting of the Milwaukee Chapter was held at Hotel Medford at 8 p. m. on Monday, November 29th. A very interesting and illustrated paper was presented by Mr. A. F. MacFarland, of the Vanadium Alloys Steel Company, on the subject, "Some Notes on the Heat Treatment and Structure Characteristics of High Speed Steel."

TRI-CITY CHAPTER

The Tri-City Chapter celebrated the founding of their chapter at a dinner meeting and smoker on Friday evening, November 5th. In order to properly portray the spirit they are showing, in getting out an attendance, the notice is printed below.

First Annual Meeting American Society for Steel Treatment, Friday Evening, November 5th, 1920

Dinner-Smoker Meeting, Davenport Commercial Club. Dinner, 7-8 p. m. $1.50 per plate. Meeting 8 p. m., sharp.

Speaker: Capt. H. B. Knowlton.
Subject: Case Hardening.

Capt. Knowlton comes to us from the Case Hardening Service Company of Cleveland, as their metallurgical engineer. He is a national authority on case hardening and this is an opportunity that no member can afford to miss.

As this is our first annual meeting, and we are in the midst of a membership drive, we expect every member to attend and bring as many prospective members as possible.

Call Moline 791 and make reservations for yourself and friends. Get your reservations in by Wednesday, the 3rd, if possible.

If it is inconvenient for any members to get to the meeting in time for dinner, please call Mr. Gust Olson, Jr., at Moline 612, and he will arrange for members to come by automobile.

All members driving cars are expected to get in touch with Mr. Olson and donate their services for this purpose.

Let's get behind this, our first annual meeting, and make it a success!

HAROLD BROWN,
Secretary-Treasurer.

The meeting was a decided success. Over 100 attended the dinner.

SPRINGFIELD CHAPTER

A very interesting meeting of the Springfield Chapter was held on November 29th, when Mr. Kaup of the Crucible Steel Company of America presented a paper on "Steel and the Man; Their Character as Developed by Treatment." Mr. Kaup developed this subject in a very interesting and entertaining manner.

ST. LOUIS CHAPTER

A very interesting meeting of the St. Louis Chapter was held on Thursday evening, November 18th, at the American Annex Hotel, preceded by a dinner. The chapter was very fortunate in being able to obtain one of its local members to present a paper—Mr. J. M. Maher, superintendent of the St. Louis Frog & Switch Company—who illustrated his talk on "Personal Microscopic Studies of Heat Treated Steel."

At the same time as the announcement was sent out, the secretary mailed to each member a mimeographed list of the members of the St. Louis Chapter and their addresses.

PITTSBURGH CHAPTER

The October meeting of the Pittsburgh Chapter was addressed by Mr. C. M. Johnson of the Crucible Steel Company of America. Mr. Johnson presented the paper that he had presented at the Philadelphia Convention. A very interesting discussion was held at the close of the meeting.

The November meeting was held on the 23rd and was addressed by Mr. Charles McKnight, Jr., on the subject "Molybdenum in Steel."

NEW YORK CHAPTER

The New York Chapter held its regular monthly meeting at the Machinery Club, 30 Church street, New York, Wednesday evening, November 17th, when it was addressed by Mr. W. R. Moore, sales engineer, Norton Company, Worcester, Mass., in a lecture on "Grinding," illustrated with stereopticon views. The meeting was preceded by a dinner at the Machinery Club.

HARTFORD CHAPTER

The Hartford Chapter has prepared their program for the season of 1920-1921 and it shows the result of a great amount of careful thought and attention. Each meeting, which is assigned a definite date throughout the year, is divided into three parts. The first part being devoted to the practical development of steel from ore to the heat treater; the second part is for the discussion of the various elements as they effect the heat

treatment of steel, and the balance of the meeting is to be devoted to a general discussion of the "Are's and Aint's of Terminology" and to a general discussion of trials and tribulations of the members.

The motto adopted by the chapter is rather interesting and is as follows: "Don't be a sponge, but if you must, once in a while give yourself a squeeze." A reproduction of their program will be printed in the transactions.

IMPORTANT ANNOUNCEMENT

A return postal has been mailed to the entire membership, requesting them to send in complete information relative to their present positions and mailing addresses, so that we may have the proper data for the publication of the Year Book of the American Society for Steel Treating, which will be issued about January 15, 1921. These postals were mailed with copies of the Constitution which were sent to the entire membership.

IMPORTANT REQUEST

In the October issue of the transactions, page 67, a paper was published by Mr. Robert M. Taylor, works engineer, American Tool Works Company, Cincinnati, Ohio, on the subject "Steel for Machine Parts, Stationary and Moving, Carbonized and Heat Treated."

A large chart was to accompany the article, giving important specifications and results of investigations. If a sufficient number of requests are received, the article will be re-printed, and the blue print of the chart accompanying the article will be with the re-printed article. If you are interested, in securing a re-printed copy, drop a postal with your address, to the Headquarters of the Society, 4600 Prospect avenue, Cleveland, Ohio.

COMMERCIAL ITEMS

The E. F. Houghton Company have issued a 50-page booklet on the "Causes of Skin Sores and Boils Among Metal Workers." This text is a record of what is doubtless the most comprehensive investigation ever made of the subject. The foreword by Mr. Charles E. Carpenter, president of the company, outlines and summarizes the main features in plain, non-scientific language, easily understood by the practical man. Wherever the recommendations made are applied in a common-sense way, the problem of skin sores and boils among metal workers is cut down, and frequently overcome entirely. This booklet can be secured by writing the E. F. Houghton Company, Third, American and Somerset streets, Philadelphia, Pa.

The Roessler & Hasslacher Chemical Company, 709 Sixth avenue, New York, has issued an interesting booklet on "The Why and How of the Heat Treatment of Steel by Cyanide." Same can be had by writing above firm.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, January, 1921 No. 4

EDITORIAL ANNOUNCEMENT

This issue of TRANSACTIONS, which is the first to be published in Cleveland since the establishing of national headquarters of the Society in that city, will reach its readers considerably behind its scheduled time. The delay has been necessitated through conditions arising in changing the place of publication and the volume of work resulting in adjusting schedules to the new conditions. Arrangements now have been completed for expeditious editing, printing, and mailing of the publication and it is believed that future delays will be eliminated. With hearty co-operation of all members of the society by sending in contributions and chapter news at the earliest moment possible, the editors will be able to place each issue of TRANSACTIONS in the hands of its readers promptly after the first of each month.

FEBRUARY ISSUE TO BE A DIRECTORY

By recent action of the Board of Directors of the Society, the February issue of TRANSACTIONS each year will be a membership directory. The next issue of the publication, therefore, will contain a complete alphabetical list of all members to date with information regarding their business connections, business addresses and mailing addresses. For convenience in reference, the members also will be classified according to geographical location. To make this directory as accurate and complete as possible, it is urged that all members who have not yet done so return to the National Secretary at once the information cards recently distributed.

RELATIVE THERMAL ECONOMY OF ELECTRIC AND FUEL-FIRED FURNACES

By E. F. Collins*

(A Paper Presented at Philadelphia Convention)

It is well known that the thermal efficiency of a fuel-fired furnace decreases rapidly with increasing working temperatures. This decrease is due primarily to the fact that the air required for combustion must be heated to the temperature of the furnace gases; the heat necessary to raise the air to this temperature usually being lost in the products of combustion as they escape. A secondary cause is the heat lost to the room from the walls of the furnace, which for convenience is called the radiation.

It is not possible to state with exactness the efficiency which may

*Consulting Engineer, Industrial Heating Devices, General Electric Co., Schenectady, N. Y.

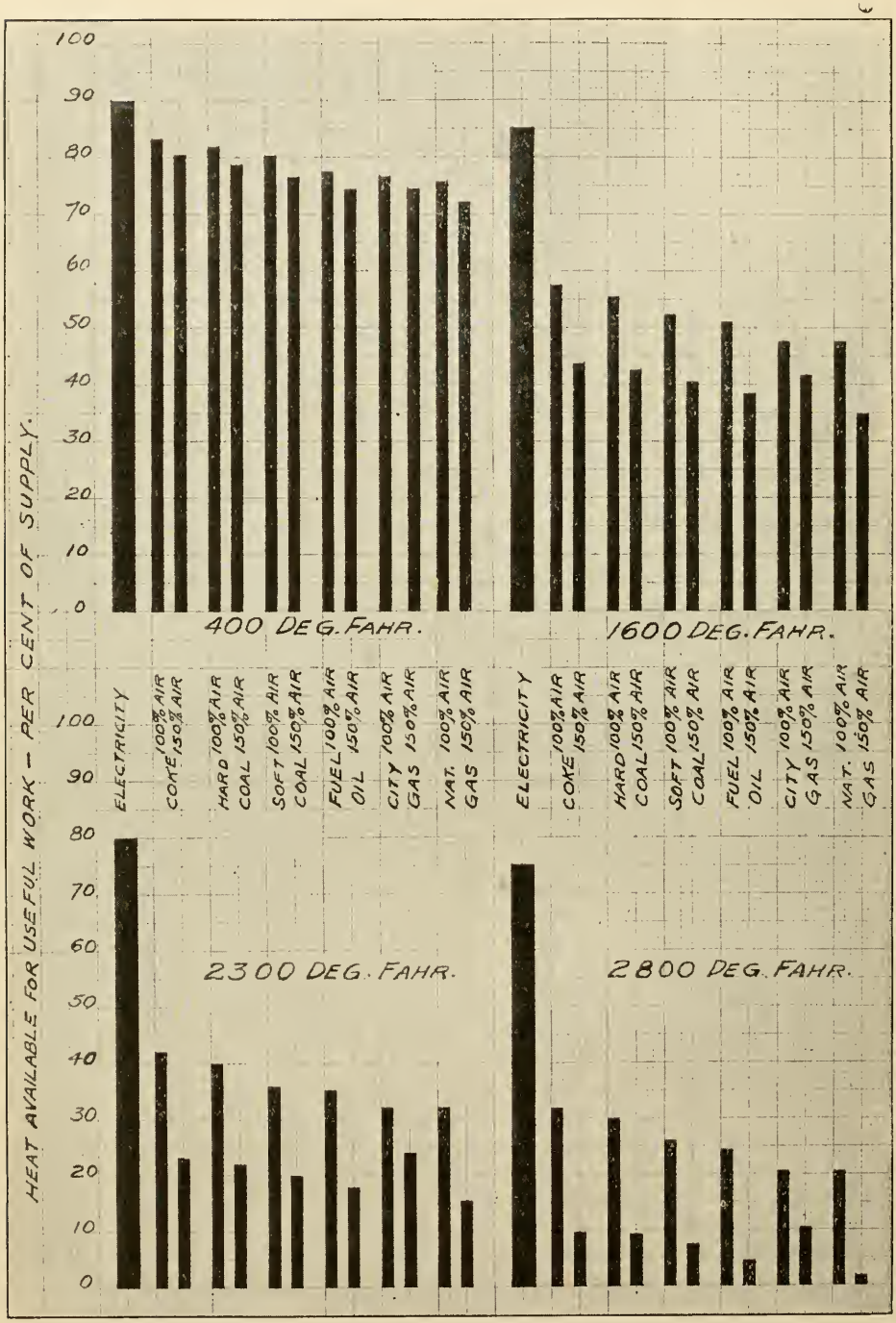


Fig. 1—Relative Thermal Efficiency of Electric and Fuel-Fired Furnaces at Various Temperatures

be realized in a furnace unless all the working conditions are known, as there are many factors which influence the amount of heat, its distribution and ultimate useful utilization. For instance, a part of the heat leaving the furnace may be recovered by preheating the fuel and incoming air, or by heating water or other materials for incidental uses; or the furnace may, in some cases, be constructed on the compensating or counter flow principle, when a considerable amount of heat may be returned to the incoming charge.

These possibilities obtain in general only in relatively large furnaces or installations, in which the plant and character of work admits of the utilization of the waste heat. The ordinary furnace and average plant operating conditions do not offer such opportunities for conservation of heat.

This paper deals with none of these compensating or regenerative schemes. The comparative thermal efficiency, therefore, is approximated by simple calculations for simple furnaces; since practically all of the theoretical heat represented by the temperature of the flue gases is lost and no approximations are necessary for completed auxiliaries.

Data showing the theoretical losses in flue gasses for various fuels at various temperatures has been submitted by others already, but it may be of interest to present this data in the form of tables and charts so as to make it available for ready reference in comparing the various fuels with electric heat, from the standpoint of thermal efficiency as well as the cost per heat unit when used for the same work and in furnaces of identical thermal loss from radiation.

The applications of electric heating are being very rapidly extended and, if the cost of electricity decreases as in the past, the point may soon be reached where the comparative cost even on a B.t.u. basis will not be unfavorable to electric heat. As a matter of fact, such a comparison at present prices is not unfavorable to electric heat at the higher temperatures as will be shown presently.

Table 1 has been compiled to show the heat losses and the cost per 100,000 B.t.u. actually utilized in useful work for various fuels including electricity, at temperatures of 500 degrees Fahr., 1600 degrees Fahr., 2300 degrees Fahr., and 2800 degrees Fahr., temperatures usually required for baking, heat treating, forging and melting respectively. The values of flue losses have been calculated for 100 per cent air; or the theoretical air required for perfect combustion, and also for 150 per cent air, or 50 per cent in excess of combustion requirements; which represents more nearly the average conditions.

Radiation losses of 15, 20, 30 and 40 per cent of the heat utilized respectively have been arbitrarily assumed for the four temperatures above mentioned and the same radiation loss has been assumed for all fuels, so that they are thus compared on the same basis; or it may be assumed that all the fuels are burned in the same furnace with perfect combustion and also with air in excess by 50 per cent.

Average calorific values of the fuels are stated and their costs per ton or per gallon, etc., are in round figures for easy calculations, so that any other costs per ton or per gallon may be applied readily.

It should be borne in mind that the heat available for useful work in the table, is the theoretical maximum for the conditions stated, perfect combustion being assumed in all cases. The values actually realized

in practice will represent a more or less lower efficiency than the tables and curves show. Note that in the case of electricity, which is perfectly converted into heat, that only a radiation loss occurs and escaping hot gases at furnace temperature do not exist as in fuel-fired furnaces.

Fig. 1 shows the heat available from Table 1 arranged in the form of charts and shows in a rather striking manner the relative efficiency of the various fuels at the four temperatures chosen. The rapid decrease of efficiency with rising temperature and increased air supply is at once apparent in the case of fuel-fired furnaces.

Fig. 2 shows the relative cost of fuels at various temperatures with 100 per cent air supply plotted as curves, and Fig. 3 shows the corresponding cost for 150 per cent air supply, the values having been plotted from the last column of Table 1. Fig. 1 shows the high ratio of heat units utilized to heat units supplied by electricity as compared with combustible fuels, while Fig. 2 and Fig. 3 show its comparative cost per 100,000 B.t.u.

For fuel cost other than those chosen, curves may be plotted by multiplying the values in the last column of the table by the ratio to actual fuel cost. For instance, for oil at 14 cents per gallon, or electricity at 1.25 cents per kilowatt hour, multiplying the values in the last column of the table by 1.4 or 1.25 and plot a new curve.

The foregoing is of course on a strictly B.t.u. basis, without regard to the expense of handling or storing fuels, or to the cost or repairs, convenience of manipulations, etc.

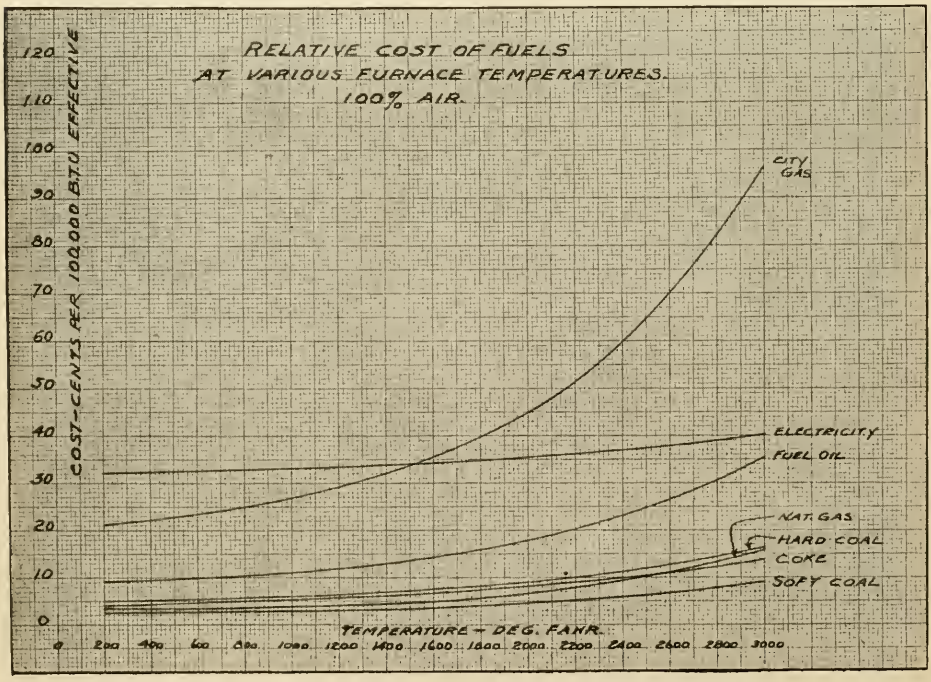


Fig. 2

It has been demonstrated that even at a higher cost per heat unit, electric heat in many cases, is actually cheaper and at the same time offers an opportunity to increase output and improve the quality of the product, so that the net results show a very considerable reduction in the manufacturing cost. Indeed, the rapid increase in the use of electric heating equipment is in itself proof that the advantage accompanying the use of electric heat in many cases outweighs any additional cost of the electric heat unit which may exist.

Coal and coke are relatively difficult and expensive to store and fire, and natural gas is restricted to comparatively local areas. Further, the supply available at present is such that it is not entirely dependable. Artificial gas is rather expensive and it is not always available in quantities so that fuel oil has naturally become the chief source of heat in many of our industries, due to the convenience with which it can be stored, handled and distributed, its concentrated thermal value and its past relatively less cost and abundant supply.

Oil, therefore, has been a popular fuel and its use has become widespread. However, the very considerable increase in its cost recently and its apparent scarcity has brought about a condition which is very trying to industrial managers, many of whom have become interested in electric heating as a solution of the fuel problem as well as many incidental problems.

It is proposed, therefore, to show very briefly some of the later applications in which electric heating has met with marked success and to indicate some of its possibilities.

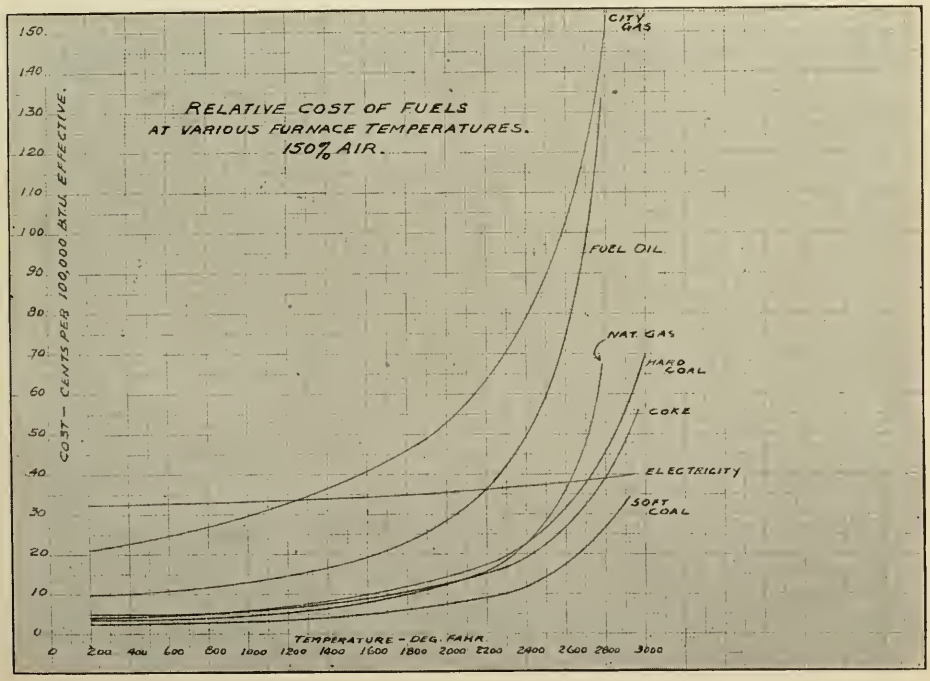


Fig. 3

The advantages of electric heating are, in general, well recognized, but the impression seems to prevail that the cost of operation is excessive. This is true in certain instances, for example, in cases where the nature of the process permits the recovery of waste heat from the flue gases.

Electric heating has been applied successfully over the entire range of temperatures, from low temperature ovens for drying and baking to high temperature furnaces for melting and refining, thus equipments are available for many applications.

TABLE I

Fuel Heat Losses and Cost per 100,000 B. T. U's.

Source of heat	Per cent of air for perfect combustion air at 70 deg. F.	Calorific value of fuel or power B.T.U.	Temperature of furnace	Rate paid for fuel or power	Cost per 100,000 B.T.U.	Losses: Per cent of available B.T.U. lost in flue gases	Losses: Assumed radiation B.T.U.	Total B.T.U. required for 100,000 B.T.U. effective	Thermal efficiency of furnace	Cost per 100,000 B.T.U. effective
Coke	100	13,000 per lb.	400 deg. F.	$10.00 per ton	$0.0385	7.5	15000	124000	80.6	$0.0477
"	150	" "	" "	" "	"	10.5	15000	128500	77.8	0.0493
"	100	" "	1600 deg. F.	" "	"	32.5	20000	178000	56.2	0.0685
"	150	" "	" "	" "	"	48.5	20000	233000	43.0	0.0898
"	100	" "	2300 deg. F.	" "	"	47.5	30000	248000	40.3	0.0955
"	150	" "	" "	" "	"	71.0	30000	448000	22.3	0.1730
"	100	" "	2800 deg. F.	" "	"	57.5	40000	330000	30.3	0.1270
"	150	" "	" "	" "	"	87.0	40000	1,011,000	9.3	0.415
Electricity	...	3415 per K.W.H.	400 deg. F.	1c per K.W.H.	$0.293	0	15000	115000	87.0	$0.337
"	...	" "	1600 deg. F.	" "	"	0	20000	120000	83.5	0.352
"	...	" "	2300 deg. F.	" "	"	0	30000	130000	77.0	0.380
"	...	" "	2800 deg. F.	" "	"	0	40000	140000	71.5	0.410
City gas	100	590 per cu. ft.	400 deg. F.	$1.00 per M	$0.17	15.0	15000	135000	74	$0.230
"	150	" "	" "	" "	"	17.5	15000	139000	72	0.236
"	100	" "	1600 deg. F.	" "	"	44.0	20000	214000	46.7	0.364
"	150	" "	" "	" "	"	51.0	20000	245000	40.8	0.416
"	100	" "	2300 deg. F.	" "	"	60	30000	325000	30.8	0.552
"	150	" "	" "	" "	"	70	30000	433000	23.1	0.736
"	100	" "	2800 deg. F.	" "	"	72.5	40000	509000	19.7	0.865
"	150	" "	" "	" "	"	85	40000	933000	10.7	1.585
Fuel oil	100	19,000 per lb.	400 deg. F.	10c per gal.	$0.0748	14	15000	134000	74.6	$0.100
"	150	" "	" "	" "	"	17.5	15000	139000	72.0	0.104
"	100	" "	1600 deg. F.	" "	"	40	20000	200000	50.0	0.150
"	150	" "	" "	" "	"	55	20000	267000	37.5	0.200
"	100	" "	2300 deg. F.	" "	"	56	30000	296000	33.8	0.222
"	150	" "	" "	" "	"	77.5	30000	577000	17.3	0.432
"	100	" "	2800 deg. F.	" "	"	67.5	40000	430000	23.3	0.322
"	150	" "	" "	" "	"	94	40000	2,330,000	4.3	1.745
Anthracite coal	100	12,000 per lb.	400 deg. F.	$10.00 per ton	$0.0425	9.0	15000	126500	79	$0.0548
"	150	" "	" "	" "	"	12.5	15000	131500	76	0.0570
"	100	" "	1600 deg. F.	" "	"	35.0	20000	185000	54	0.0805
"	150	" "	" "	" "	"	50.0	20000	240000	41.7	0.1020
"	100	" "	2300 deg. F.	" "	"	50	30000	260000	38.5	0.1105
"	150	" "	" "	" "	"	72.5	30000	473000	21.1	0.2010
"	100	" "	2800 deg. F.	" "	"	60	40000	350000	28.6	0.1490
"	150	" "	" "	" "	"	87.5	40000	1,120,000	8.93	0.476
Bituminous coal	100	12,550 per lb.	400 deg. F.	$5.00 per ton	$0.020	11	15000	129000	77.5	$0.0258
"	150	" "	" "	" "	"	15	15000	135000	74.0	0 0270
"	100	" "	1600 deg. F.	" "	"	38.5	20000	195000	51.3	0.0390
"	150	" "	" "	" "	"	52.5	20000	253000	39.5	0.0506
"	100	" "	2300 deg. F.	" "	"	55	30000	289000	34.6	0.0578
"	150	" "	" "	" "	"	75	30000	520000	19.2	0.1040
"	100	" "	2800 deg. F.	" "	"	65	40000	400000	25.0	0.0880
"	150	" "	" "	" "	"	90	40000	1,400,000	7.15	0.2800
Natural gas	100	1100 per cu. ft.	400 deg. F.	30c per M	$0.0273	16.2	15000	137000	73.0	$0.0374
"	150	" "	" "	" "	"	20	15000	144000	69.5	0.0393
"	100	" "	1600 deg. F.	" "	"	44	20000	214000	46.7	0.0585
"	150	" "	" "	" "	"	59	20000	292000	34.2	0.0797
"	100	" "	2300 deg. F.	" "	"	60	30000	325000	30.8	0.0886
"	150	" "	" "	" "	"	81	30000	685000	14.6	0.1870
"	100	" "	2800 deg. F.	" "	"	72.5	40000	510000	19.6	0.1390
"	150	" "	" "	" "	"	97.5	40000	5,600,000	1.8	1.530

Electric ovens for baking enamel are so widely used and their advantages so well known that it is hardly necessary to do more than refer to them here. Their extensive use for enameling automobile bodies and parts, in other words, where a superior finish is required, is sufficient argument as to their economy.

Ovens for baking foundry cores are also yielding excellent results from the standpoint of efficiency and net cost, particularly for small cores, in which breakage and loss from uneven baking usually is a very considerable item. The uniform distribution and automatic

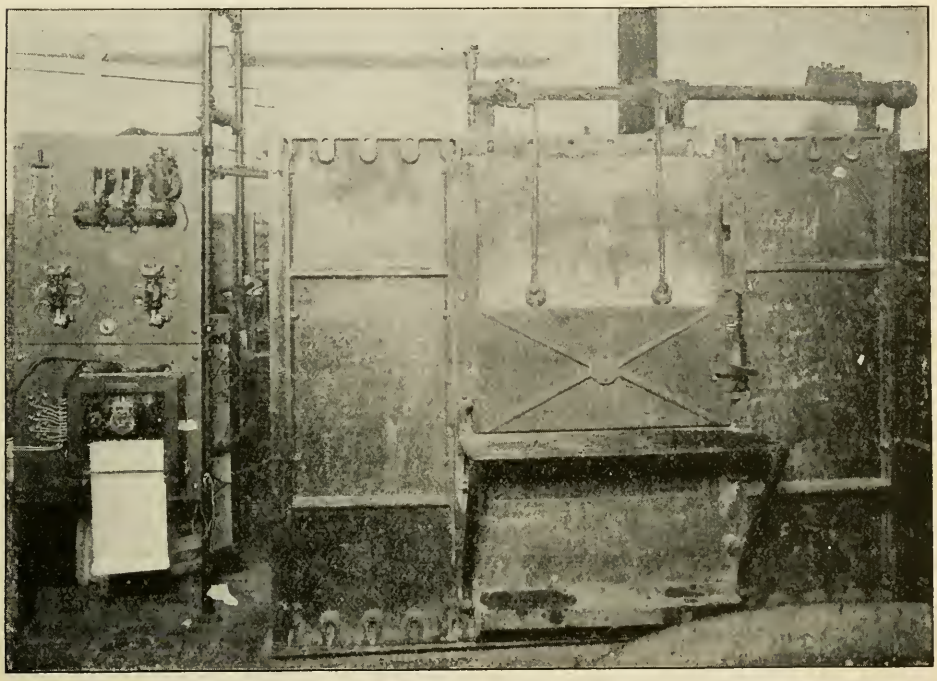


Fig. 4—Electric Resistance Furnace with Panel and Instrument for Automatic Temperature Control

temperature control possible with electric heat considerably shortens the time required for baking and produces perfectly baked cores, thus the losses are reduced and rejects seldom occur.

Several installations have been made in wire mills, all of which have showed a substantial saving. The following data is typical, and shows the actual cost of baking steel wire to remove grease and drying it after pickling. These are operations which require no refinement, since it would not be expected that electric heat would have any advantages whatever if judged on a B.t.u. basis alone.

The installation referred to has both electric ovens and coke-fired ovens of the same dimensions. Electricity is by far the most expensive fuel on a B.t.u. basis at drying and baking temperatures as shown in Figs. 2 and 3, while coke is among the cheapest possible fuels. Therefore, a direct comparison in the same plant is interesting as follows:

Tests of Electric and Coke-Fired Wire Baking Ovens

Baking at 525 Degrees Fahr., Cycle 10-12 Hours

Electric	Actual test 10 per cent output	Test results reduced to 100 per cent output
Cost of power per net ton of steel	$5.087	$ 1.19
Annual charges per net ton	7.839	0.727
Total cost per net ton	$12.926	$ 1.917
Coke		
Cost of coke per net ton of steel	0.921	.171
Annual charges per net ton	21.368	1.983
Total cost per net ton	$22.289	$ 2.154

Baking at 350 Degrees Fahr., Cycle 1-10 Hours

Electric	Actual test 35 per cent output	Test results reduced to 100 per cent output
Cost of power per net ton of steel	$0.787	$ 0.515
Annual charges per net ton	0.648	0.187
Total cost per net ton	$1.436	$ .702
Coke		
Cost of coke per net ton of steel	$0.253	$ 0.146
Annual charges per net ton	1.766	0.510
Total cost per net ton	$2.019	$ .656

The normal output of these ovens is considerably less than the maximum capacity, so that "normal" results, or results from observation are given, as well as results which might be expected if they were operated at full capacity.

These figures show, as might reasonably be expected, that the cost of fuel in the coke-fired ovens is practically negligible in comparison with the cost of handling, repairs and other charges. In the electric ovens the cost of power is the principle item.

Perhaps a more familiar example is an ordinary hearth-type furnace as used for hardening tools, dies, cutters, etc. Tests were run on an oil furnace and on an electric furnace, both having about the same hearth area and doing the same kind of work at the same temperatures.

Tests of Electric and Oil-Fired Hardening Furnaces

	Electric	Oil-Fired
Dimensions heating chamber	30 x 36 x 42 inches high	48 x 24 x 20 inches high
Length of test (heating steel)	107 Hrs.	31.75 hrs.
Average temperature held	1450 deg. F.	1400 deg. F.
Amount of steel heated	1451 lbs.	2670 lbs.
Amount of steel heated per hr.	13.6 lbs., 84 lbs. (Calc)	84 lbs.
Fuel and power to hold at 1400 deg. F.	8.04 K. W. H. per ht.	1.65 ga. per hr.
Fuel and power while heating steel	8.96 K. W. H. 12.36 K.W.H. (Calc)	1.9 gal. per hr.
Fuel and power rate	1.25c per K. W. H.	14c per gal.
Fuel and power per lb. of steel	0.65 K. W. H. 0.147 K.W.H. (Calc)	0.022 gal.
Cost per hour to hold 1400 deg. C.	10 c	23.1c
Cost fuel and Power per lb. steel	0.008 0.0018 (Calc)	0.0030

With both furnace tests corrected to the same output of 84 pounds of steel per hour at 1450 degrees Fahr., the ratio of cost of oil burned to the electric power required is 0.0030 divided by 0.0018 or about 1.7.

In other words, these tests show cost of operating with oil to be 70 per cent greater than heating by electric power.

It may be said that this electric furnace is provided with automatic temperature control and a time switch which throws off the power at the end of the working day and throws it on in the early morning so that the furnace is always ready for use. This furnace and control equipment are shown in Fig. 4.

It is obvious from the above data that the fuel used in actually heating steel is almost negligible in either furnace, which is of course well known. The data shows that the cost of maintaining temperature in the oil furnace is more than double the cost for the electric furnace.

This may perhaps be surprising to many who base their calculations entirely on the relative cost of B.t.u's. It would be still more surprising if the cost of repairs and fixed charges could be included in the comparison. This cost for the electric furnace is practically zero. The figures for this size of oil furnace are not available to the writer, although they are probably available from other sources.

The fact which it is desired to emphasize is that the oil furnace referred to, is typical of thousands in regular use on heat treating, which could be heated by electricity for less than half the fuel cost alone, to say nothing of the saving in repairs. This represents a considerable loss to the individual manufacturer, but in the aggregate it is an enormous economic waste.

An interior view of this type of electric furnace is shown in Fig. 5 which, however, is a somewhat larger furnace than shown in Fig. 4.

A large number of these furnaces are in daily operation for such work as annealing, hardening and carbonizing for which they are particularly well suited. The furnace shown in Fig. 5 is one of a pair which are used for carbonizing. All of these furnaces are equipped with automatic temperature control.

The furnaces referred to are of the metallic resistor type and are suitable for operation to 1000 degrees Cent. (1800 degrees Fahr.). For higher temperatures, such as are required for forging and melting, a form of carbon furnace is available.

There are a number of electric brass melting furnaces in operation, most of which have been built in the last few years, in fact, furnaces being installed today for melting brass are largely electric furnaces. This is an index of the rate at which electric heating is being adopted, and it seems safe to predict that it will supplant fuel oil to a considerable extent for such purposes within the next decade.

Enormous quantities of oil now are used in the operations of annealing, heat treating and forging. The electric furnaces previously referred to are ideal for this annealing and heat treating, and a resistance furnace now is being built for forging steel on a commercial scale. This furnace, which is designed on thoroughly tested principles, appears to be very promising.

It is unnecessary to dwell upon the many inherent advantages of electric furnaces, such as easy and positive temperature control, absence of noise, products of combustion and excessive heat duplication of results, etc., as these features are well known. It is desired, however, to emphasize the fact that, contrary to the general impression in the past, the cost of electric operation is not excessive, but in many

cases is no greater and often is considerably less than with fuel-fired furnaces.

The era of electric heating has begun, and it may well be expected that electricity will ultimately be used as widely for industrial heat as it is for industrial power at the present time.

In conclusion, the real object of this paper is to call attention to the fact that fuel cost does not determine heating cost or overall manufacturing costs. It is essential that heating propositions receive careful study and all conditions associated with the process be considered with each type of fuel furnace and the electric furnace. Then and then only should it be decided whether heating should be done with electricity or with some kind of fuel.

The writer is in accord with the observations of a prominent furnace engineer and builder which were as follows:

"To heat with coal, cook with gas, and light with electricity is considered good practice in a dwelling, yet some people think one type of furnace and one fuel is good enough for the more complicated heating operations in a factory.

"There are furnaces and fuels just as there are shops and shops, but the furnaces and fuel you require should be selected to suit your needs for the same reason that your shop is.

"Fuel cost does not determine heating cost. One is at the start and the other at the finish of the operation. The way to lower the latter is to employ the furnace and fuel best suited to the operation and use both efficiently.

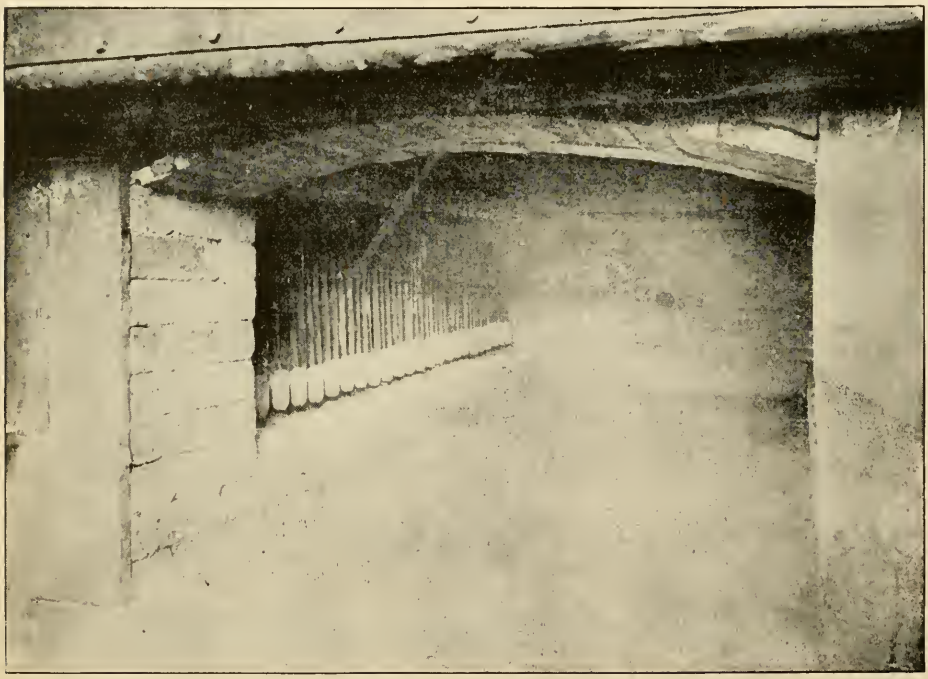


Fig. 5—Electric Carbonizing Furnace with Door Open. 79 Inches Deep, 36 Inches Wide, 29 Inches High, 60 Kilowatts, 220 Volts, 3 Phase, 925 Degrees Cent. Operation

"The B.t.u.'s you can get for a cent do not determine the quantity or quality of product you can get for a dollar any more than the price of kerosene determines the cost per ton mile of an automobile. It is the nature of the operation combined with the furnace that determines the fuel use."

DISCUSSION OF MR. COLLINS' PAPER

MR. DIEMER: Due to the fact I didn't get the focus on the chart I would like to ask the speaker what the cost of the electricity was at the high temperatures?

MR. COLLINS: That was the cost for one hundred thousand b. t. u. on the 100,000 b. t. u. basis.

MR. DIEMER: The rate per kilowatt?

MR. COLLINS: This is figured on a one-cent basis.

MR. CRUMBACKER: Do you know of any case where a forge shop uses electric furnaces for heating? Do you know of any company using electric heat for heating rough stock?

MR. COLLINS: I do not know of any company using it at the present time. Arrangements are being made for a test of the electric furnace in forging work.

MR. EVANS: I would like to ask the speaker if he has any general data on the type of furnace described as to the cost per kilowatt comparable to city gas in any given figures, that is, say take dollar city gas, what cost per kilowatt do you compare electricity on an equal basis?

MR. COLLINS: If these slides had shown up a little more clearly you would have seen that the answer to that is variable, depending upon your temperatures. A simple figure which will represent that can not be given safely, but I should be glad to show you these charts at any time, or if they should be printed, you will have an opportunity to check it up there. It is a question that cannot be answered simply by giving you rates, for it is misleading.

MR. EVANS: I thought perhaps you had a figure that was approximate for city gas, that is, in heat treating tool steel.

MR. COLLINS: No, that cannot safely be done unless you know all the conditions surrounding it. It would be simply folly to give you a figure, because it would not mean anything unless you know all the conditions surrounding it.

QUESTION: Do you know of any cases where the electric furnace might be placed in a wire mill?

MR. COLLINS: Well, coke would be the fuel used.

MR. HILLMAN: I would like to know whether the speaker knows of any research on the lines of electricity as heat for rotary furnaces?

MR. COLLINS: The question, as I understand it, is whether I know of any furnaces of the rotary type that are equipped electrically.

MR. HILLMAN: Whether any have ever been equipped that way and found unsatisfactory.

MR. COLLINS: I do not know of any of the rotary type that have been equipped and found unsatisfactory.

MR. HILLMAN: I never have been able to see any.

MR. COLLINS: There are furnaces operating of that type. Some of the most recent ones we have operating in Cleveland. I can readily refer you to people, later if you care to know who have them.

MR. HILLMAN: I have operated the rotary furnaces for some time, but I was wondering whether there was any possible comparison.

MR. COLLINS: Well, of course, there are different types of rotary furnaces. I am not sure to just what type of rotary you have reference. These of which I speak are the rotary disk type, the annular ring type. I am speaking of the type exhibited here by the American Gas Furnace Co., the rotary cylinder type.

MR. COLLINS: I have no data that I can give you on that type.

MR. STAFFORD: What is the largest chamber capacity of electric furnaces that you would use for annealing bulky material?

MR. COLLINS: I do not know whether I can give you the largest that has been used but I can tell you of some that have been used for heat treating. Some of the largest ones were used during the war for the heat treating of guns. At the present time the largest one is being constructed, which is something like 105 feet deep and cylindrical, 10 feet in diameter, and requires 2700 kilowatts for heating. That is a single furnace. We have other furnaces which were 6 feet in diameter, and 25 to 40 feet deep. Those are some of the larger sizes and kilowatts run all the way from 400 up to 700 and 800. There are others for somewhat lower temperature work installed in the Washington navy yard which required about 100 kilowatts to heat. Those had chambers 80 inches in diameter and were 88 feet long. Of course, there is nothing that stands in the way of building the furnace horizontally or vertically or of any chamber dimensions that might be required, or for any tonnage.

MR. THORNE: Is there any difference in the length of time that it takes between city gas and electric current for bringing a certain quantity of metal to heat?

MR. COLLINS: Ordinarily you heat stock more rapidly by radiation than you do by convection, and if you take the open fired gas furnace where a large part of your heating is by convection of hot gases as against the electric furnace where you are heating by radiation, you should get a shorter period for heating in the electric than in the gas furnace. If you take a gas furnace that has a muffle which does not restrict the flow of heat, in that case you would heat by radiation also, and your time of heating ought to be practically the same.

MEMBER: The all-important cost problem comes up and it is impossible to give comparative cost in general, but if we take definite furnaces and compare them, then the cost could be set. For instance, it would be very interesting to determine the fuel cost of an oil or gas-fired, continuous hardening furnace which puts through 100 pounds of hardenings per hour, and the kilowatt energy cost required for a corresponding electric furnace, both furnaces built by the best available concerns.

MR. COLLINS: That comes very near to being the conditions in this data which I gave. The furnaces described are operating on tools, dies, etc., with an output of 84 pounds, and in that case, with electricity at 1¼ cents and oil at 14 cents a gallon, the cost per pound of heating by oil is 70 per cent greater than the cost per pound by electricity.

MR. KAUFMAN: I would like to ask the speaker what is the life with temperatures not exceeding 1800 degrees?

MR. COLLINS: Speaking of the nichrome element, you want to know what the life of that is, running up to 1800 degrees Fahr. That is something that I can not tell you, since I have no data on it. We have

not had a breakdown at that temperature due to temperature. I might say that in furnaces which were installed about a year previous to the armistice, and which operated many of them night and day on the heat treating of gun forgings, the element running up around 1600 to 1700 degrees, at the end of that year's operation there was absolutely no way to detect that element differed in any way from the original element, either due to oxidation or crystal change by any method whatever that we could use to determine that there had been a change. Evidently it was identically the same as when it was first installed in the furnace, with the exception that the surface color was slightly darker. Of course, that metal is protected by a very adherent scale which forms a protection, and that scale had formed of course very early in the operation. You would not call it a scale, either; it resembles a barb wire finish. After the war in the construction of the large furnace, 105 feet, 2700-kilowatt, I was speaking about a few minutes ago, those same resisters that operated for this year in some of these temporary gun plants equipped with furnaces were reformed and put into the furnace along side new material. We actually did that, and when you can take old cloth that has worn a year and put it alongside new cloth and make a new garment of it, I think it speaks pretty well for the life of the resister.

PYROMETERS AND THEIR APPLICATION TO STEEL TREATING

By J. D. Andrews*

(A Paper Presented by Title at Philadelphia Convention)

Some years ago, when the layman using a pyrometer was not so familiar with "what makes the wheels go round", a customer telephoned complaining that an instrument recently purchased would not operate. To clear the trouble, we visited the plant and found to our amazement that he was endeavoring to measure the temperature by inserting into the heated zone the dial of an expansion pyrometer, rather than its stem. From the standpoint of pyrometer ethics, few manufacturers today would be guilty of an error of this kind.

Pyrometers today are an essential part of the equipment of progressive steel treating plants, although it is but a decade ago that a manufacturer was depending on the unaided judgment of the furnace operator, or had to reply on crude instruments for the determination of temperature.

While an observing man would with practice become expert in judging temperature by color, it was difficult to impart to others knowledge thus gained and ability to duplicate results necessitated good health on his part and freedom from light fluctuations. This latter consideration required excluding daylight from the heat treating room, so that during the short winter days, coming to the shop before sunrise and leaving after sunset, the operator might as well have worked in a mine, so far as daylight and ventilation were concerned.

But a few years ago, it was necessary to convince a manufacturer of the advantages of pyrometers compared with the rather crude methods then employed for measuring temperature. Today, he is educated to the value of

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such instruments for the efficient operation of his furnaces, and is chiefly interested in the comparative merits of the equipment on the market.

Instruments for measuring temperature have been developed to operate on calorimetric, fusible cones, shrinkage, radiation, optics, and thermoelectric principles. The thermoelectric type is most widely used in the steel industry and consists essentially of three parts, namely, the thermocouple for insertion in the heated zone, the instrument proper for indicating or recording the temperature, and the connecting wires.

In each instance, the conditions to be encountered and the results desired govern calibration of the instrument, composition of the thermocouple rods and their protection, as well as composition of the leads and type of insulation. The instrument manufacturer provides apparatus accurate to within a small percentage, but operating conditions vary so widely, it is difficult and usually undesirable for him to stipulate working temperatures. When installing a pyrometer system, it is policy to study matters for a few days, noting that duplication of temperature, as shown by the instrument, invariably means duplication of results.

Thermocouples can be made very sensitive to temperature changes by using wire of small cross section having a low temperature coefficient. By using wire of large cross section, life can be increased but with the introduction of a time lag which in some works is objectionable. As stated above the thermocouple wires should be selected to meet the conditions of the particular work in hand.

Practically any two wires of different composition, when joined together and the junction heated, will generate a small voltage. In selecting wire for thermocouples, it must necessarily have ability to withstand the temperatures to be measured and must be of homogeneous material, generating high milivoltage constant in amount, so that temperatures may be duplicated. Experience has shown that the following combination of materials give good results for the temperatures indicated:

Materials	Upper Limits
Iron-constantin or nickel chromium constantin	1400 deg. Fahr.
Nickel-chromium-nickel-aluminum	2000 deg. Fahr.
Platinum-platinum 10 per cent rhodium	3000 deg. Fahr.

Platinum thermocouples generate but 20 millivolts at 3000 degrees Fahr. and this voltage usually is desirable for full scale reflection. As base metal thermocouples generate several times this millivoltage, ample torque is obtained with a lower full scale calibration; in addition they are more robust and but a fraction of the cost, hence their general use for temperatures below 2000 degrees Fahr. If properly protected and used below their upper limits, thermocouples will maintain their millivoltage and give good results. Where used near their upper limits, it is desirable that they be handled as little as possible as nickel tends to crystallize and iron to oxidize.

Base metal thermocouples are provided of selected wires, guaranteed to reproduce a given millivoltage within plus or minus 10 degrees Fahr. These couples have no satisfactory means of restandardizing and when they drop off in millivoltage must be cut back or discarded.

Some years ago the practice was adopted of shunting base metal thermocouples with manganin wire, reducing approximately two millivolts the normal potential at the terminals. This plan enables interchangeability and permits restandardizing at any time by adjustment of the shunt, to within plus

or minus 5 degrees Fahr. Good results have been obtained, although, where extremely long thermocouples are to be used, there is theoretically some objection to this practice.

For constant use about 1800 degrees Fahr, thermocouples of platinum-platinum rhodium protected with tubes impervious to gases and mechanically strong are recommended. Heating these thermocouples by the passing of an electric current will restore them to normal when not too badly contaminated.

It is desired to keep the thermocouple wires protected from furnace gases and from oxidizing conditions in order to insure life. Protecting tubes used should be immune to the action of heat and chemicals, mechanically strong and good heat conductors. As it is only to a limited degree that we find all these qualities in any one material, it is of prime importance in choosing tubes to bear in mind the particular conditions to be encountered. Outside the furnace mechanical strength alone is necessary, hence, tubes of special material need protect only that section of the thermocouple in the heated zone, extending far enough through the furnace wall so that the balance of the couple, protected with a wrought iron tube, will not be injured by the heat or gases. This construction is a saving in expense as against the unnecessary use of full length tubes of special material.

It is recommended that where possible, base metal thermocouples be inserted eight inches or more into the heated zone, to prevent conductivity of the wires and protecting tube from reducing temperature of the hot junction in small furnaces this amount of insertion is not always practical due to the size of the chamber. Results, however, may be readily duplicated with less insertion, provided the couples are installed in a permanent manner. Duplication of results is usually of more importance than absolute temperature, for heat at best is only comparative and does not admit of direct measurement such as a mass which may be weighed or a length which may be scaled.

The welded junction between the two wires of the thermocouple is termed the hot end, and this is inserted at the point where it is desired to measure the temperature. This hot junction should be so placed in the furnace chamber as to be near the work under treatment but shielded from the flash heats of firing. Some endeavor to so place this end of the thermocouple that it may be seen through a sight hole in the furnace door, and thus enable comparison by color with that of the work being treated.

Where the temperature will not exceed 1300 degrees Fahr. these wires are insulated from each other with asbestos tubing or string painted with a solution of sodium silicate. Above 1300 degrees Fahr., insulation of lava or porcelain is to be recommended, as asbestos has a tendency to disintegrate, resulting in the possibility of the thermocouple short circuiting. For convenience in connecting with the lead wires, the outer or cold ends of the thermocouple are terminated at binding posts.

The electromotive force generated by a thermocouple is dependent on the difference between the hot and cold ends, hence it is desirable that the cold end be maintained at a constant temperature. To accomplish this result, compensating leads are employed similar to the couple, or of a material generating practically no millivoltage against the thermocouple wires when subjected to temperature changes. These join at the binding posts of the couple and extend to a point free from radiation or changes in atmospheric conditions. A constant cold end temperature may be maintained within a water or steam jacket at the end of a pipe well in the ground, or with a com-

pensating box temperature, of which is automatically held at a fixed point by a thermostat making and breaking the circuit of electric lamps within the box which furnish the heat.

At times the question has been raised as to whether the brass stud between the thermocouple and compensating leads would not cause incorrect results. No error occurs where the stud is the same temperature throughout its length, for then the positive millivoltage generated at one end is offset by the negative millivoltage at the other.

Thermocouples to be used in metal or salt baths are usually made up in right angle form so that the cold end is away from radiant heat and out of the workmen's way. The hot end should reach about midway of the bath. Thermocouples used in baths which are electrical conductors, or in furnaces having outer shells of metal, should employ double conductor wire and double arm switches to eliminate any possibility of one thermocouple interfering with another. Where inserted through a non-conducting material, such as brick work, a single arm switch is satisfactory, permitting an individual wire to each thermocouple with a common return.

Wiring of an electric pyrometer system offers no fire hazard as only a millivoltage is generated by the thermocouple. It is good practice, however, for the sake of mechanical protection and a neat, workmanlike installation to run this wire in conduit. Care should be taken to see that all joints are soldered and taped and that connections at binding posts are clean and tight. Where the wiring will be subjected to a temperature over 100 degrees Fahr. it is recommended that the insulation be of asbestos or of a slow burning material.

The LeChatelier type suspended coil galvanometer, for use as a thermoelectric pyrometer, was first made in Europe. In practice it was found that such delicate laboratory apparatus necessitated careful leveling as well as shielding from vibration, which led to the development in this country of a galvanometer system having a double pivoted rod form with steel pivots mounted in sapphire bearings. This construction made a more rugged shop instrument, but for some time the internal resistance was not above 10 ohms, necessitating in each instance, calibration for a given resistance of the external circuit.

Tests of these low resistance instruments have shown an error of as much as 18 degrees Fahr. when 50 feet of double conductor copper leads were subjected to a change in room temperature of 50 degrees Fahr., which made it desirable to use leads of No. 12-gauge B & S standard wire to keep down resistance of the external circuit.

Standard instruments today have the parts tooled up for interchangeability. They have internal resistance of some 15 ohms per millivolt, or over 600 ohms for a range of 2000 degrees Fahr. so that possible errors, compared to a 5-ohm instrument, are but 1-120th. With this internal resistance, a variation of over 3 ohms in the external circuit is permissible with an observable error of not over 0.5 per cent, equivalent to some 900 feet of No. 12-gauge double conductor wire.

By the use of an aluminum movable coil form, instruments are built with an internal resistance of 30 ohms per millivolt. The movable element is wound with enamel wire of but 0.003-inch diameter, which is much thinner than the silk insulated wire formerly used and permits more ampere-turns on a coil of a given width. The aluminum pointer is of tubing 0.012-inch out-

side diameter, 0.008-inch inside diameter, having a wall thickness of but 0.002 inch. The assembled movable element complete with pointer and springs, weighs but 526 milligrams.

Where the instruments are to be located near the furnaces that they may be consulted frequently by the attendant, as is common practice, it is important to keep the temperature coefficient as low as possible. Present construction has lowered this to about one-twelfth the former figure so that normal changes in room temperature will now cause no appreciable error.

An improvement in the wiring design of a millivoltmeter has been worked out by Messrs. Harrison and Foote of the bureau of standards, Washington. This permits balancing a series against a parallel circuit in the elimination of line resistance, no standard cell or other battery being required aside from millivoltage generated by the thermocouple. This principle may be applied to either indicating or recording instruments, although its field is chiefly as a portable, where line resistance is to be cared for but a rugged movable system with strong spring control is desired. When once adjusted for line resistance, this instrument is direct reading and shows readily fluctuations in temperature at the thermocouple which may be as much as a mile away.

The millivoltage generated by a thermocouple may also be measured by a potentiometer. While independent of resistance of the thermocouple circuit, the potentiometer like all instruments, has its limitations for the standard cell employed to regulate current in the battery circuit, is subject to deterioration if exposed to temperatures below 40 or above 150 degrees Fahr. In operation, the battery circuit must be balanced until its voltage offsets that of the thermocouple circuit, when no current flows through the galvanometer. These small batteries in time also wear out and require replacement.

An improved type of potentiometer has recently been perfected, so that a portable instrument can now be provided with a scale length of approximately 96 inches, permitting graduations of 1-50 millivolt for a full scale of 50 millivolts. This scale is made in the form of a spiral and is direct reading, being automatically adjusted to position as the slide wire resistance of the battery circuit is balanced against the millivoltage of the thermocouple. This potentiometer is supplied with a standard cadmium sulphate cell, having an unsaturated solution and neglibible temperature coefficient. It conforms to recommendations and specifications of the bureau of standards.

A pyrometer system may be likened to a chain, the strength or accuracy of which is but equal to its weakest link; hence, when going in for closer than commercial accuracy, all factors should be strengthened.

It has been the practice in the past when installing pyrometers to locate the indicating instrument near the furnaces for ready reference by the operator, recorder instruments being placed in the office of the superintendent that he might supervise and study the furnace temperatures.

Economy of furnace time frequently makes it desirable to carry the temperature higher than the work should ever reach, so that timing the period of heating is only secondary in importance to the temperature of the furnace. As recording instruments give a time temperature check on heat treating operations, they are daily coming into greater use in the shop. Their use by the operator enables closer regulation of temperature, for he may note the tendency to vary from normal and check such changes at the start.

One automobile firm has installed near the furnaces for guidance of the operators some 30 recording pyrometers of the duplex type, a number of which are used in connection with lead hardening of gears. There is a sharp drop in the temperature recorded when a cold charge is placed in the pot, hence, the chart serves as a production record to show the number of charges treated in a given time. Experience has shown that these records stimulate friendly rivalry between furnace operators, that an inexperienced man working alongside an expert can quickly improve his product, and that the record chart will insure each batch of work heated in accordance with instructions.

Recording pyrometers employ a clock mechanism to time the feed of the chart and to operate the depressor mechanism. These instruments were originally designed to mark with pen and ink and depended on capillary action to feed the ink from a small reservoir carried by the pen arm. It was difficult to so balance the delicate movable system that it would read correctly with the ink reservoir either full or empty, and changing atmospheric conditions caused the ink to dry and clog the pen, or to become fluid and feed too rapidly to the chart.

A sensitized chart was next tried, where the pen marked through an emulsion or coating. This idea has likewise been abandoned, for the pen had a tendency to collect emulsion and adhere to the chart, and if the latter were brought near a radiator or other warm object, the record would be destroyed.

As made today, the disk chart recorded employs a transparent chart backed by a carbon. A white sheet is interposed between the two so that while in operation, the record may be readily seen in contrast against the white background. No fixing solution is required to make this record permanent and it is ready for file as removed from the instrument.

The depressor mechanism, as operated by the clock, forces the stylus against the chart surface once a minute or oftener, leaving a carbon mark to show its position. Between depressions the stylus is free to assume change in position as the thermocouple hot junction changes in temperature.

A recorder in far greater demand today, employs a strip chart which has numerous advantages over the disk chart instrument just described. Throughout the range, these charts have uniform time spacing of 1⅛ inches per hour. The stylus is depressed at regular periods by the clock mechanism onto a carbon marking band which passes over the chart similar to a typewriter ribbon.

The position of the stylus at the instant is shown by the dot left on the chart; this may also be read on the indicating scale attached to the depressor bar. As these dots occur once a minute or more frequently, a complete time-temperature record is made without friction from the pen trailing. Both chart and carbon marking ribbon operate for 60 days without replacement, but the chart may be torn off for any period where it feeds through a slot at bottom of the instrument case.

This instrument is provided with a hardwood protecting case of dust-proof construction, having a 7-inch space beneath the instrument proper into which the completed chart drops. A reroll attachment for the chart can be furnished where desired to operate from the clock mechanism.

This strip chart instrument is equipped with a doublebarrel spring clock, especially designed for uniform power. This clock has the well known Seth

Thomas escapement, is mounted in a separate dustproof metal compartment with plate glass front, and arranged for winding from outside the instrument case. Means are provided for stopping and starting and for adjusting the timing. With this construction, the operator has little occasion to touch the instrument mechanism, which minimizes the chance of his disturbing the balance of the movable system.

Where temperatures relate to each other, it is often desirable to have two or more records on one chart for comparative purposes. This need has developed the duplex type recorder, in which two pens with separate galvanometer systems operate on a single chart through a marking ribbon as described above.

Further development has brought out the multiple recorded, making from one to 10 records on a chart. This instrument likewise employs a carbon ribbon for marking, but in this instance five colors are used. Records one to five are made with a single dot of the stylus, while records six to 10 are made with double dots, repeating the color scheme. The clock mechanism, in switching the galvanometer from one thermocouple to another, likewise shifts the width of ribbon in order to give a distinguishing color for each record.

Where an operation is to be duplicated repeatedly, it is often desirable to trace lines on the charts to show the allowable variations thus enabling the operator to more readily follow instructions. These lines of course, can be included when printing the charts.

Loss of record would naturally result if the attendant neglected to wind the spring clock. Today, however, an electrically-driven clock can be supplied with any recording instrument.

During the war, certain industries had difficulty in securing men able to use pyrometers with intelligence. To meet this condition, a battery of red, white and blue electric lights was installed over each furnace, to indicate high, normal and low temperature. Where mounted in a vertical position, all concerned could see from a distance which furnaces were operating above or below normal, the lights being controlled by an operator at a central station switchboard, held responsible for maintaining the correct temperature in all furnaces. This system was chiefly adapted to day-in and day-out operation on work requiring long period heats.

In some installations the white light was used in combination with the red, to indicate a given number of degrees above normal, and the red light only when this safety zone was exceeded. The same combination with the blue light covered temperatures below normal.

A development of this system eliminates the central station operator, as the lights may now be automatically controlled by relay circuits actuated by the instrument. It has been but a step further to employ these relay circuits to actuate electric switches or valves, so that temperatures may be automatically controlled whether the source of heat be electricity, steam, gas or oil. Control is possible within one per cent of the scale range.

Control of electrically-heated furnaces merely requires opening or closing a circuit or the operation of a rheostat. This has been comparatively simple and numerous installations have been made.

Control of steam-heated equipment is similar to that of gas-fired furnaces operating on the single pipe system and is less complicated than that in which the valves must operate simultaneously on both gas and air. Gas control is

working out well at a number of plants and the records show closer regulation than has been possible with hand control.

Control of oil-fired furnaces requires but a minute adjustment of the valves to alter the temperature, hence, proper filtration of the oil is of prime importance to prevent clogging. A number of installations of this type which look very promising have been made and the weak spots are being gradually eliminated.

With any installation for automatic control of temperature, the conditions must be studied and the equipment so adapted as to give the results desired.

Conditions obtain where the temperature to be measured is so high that directly inserting thermocouples in the heated zone would give but very short life. In other cases, one could not very well reach with the hot junction of a thermocouple, so that it is necessary to employ either optical or radiation pyrometers.

A radiation pyrometer consists of a sensitive thermocouple placed in the focusing point of a concave mirror at the rear end of what is termed a radiation tube. The rays of heat from the furnace strike the mirror and are brought to a focus on the hot junction of the tiny thermocouple, the millivoltage generated being measured on a direct-reading instrument.

Optical pyrometers depend on comparison of light or color with the object under treatment, thus there is the personal element with which to contend. With either radiation of optical instruments, correct readings depend on a fairly clear atmosphere, so opaque gas would interfere with true radiation, as would also intervening flames of temperature higher than the object to be observed.

A recording pyrometer has been designed to show graphically the temperature at which steel goes through the molecular changes termed transformation points. The instrument proper is a recording millivoltmeter with a movable coil wound in differential. It is operated with two thermocouples, one of which registers true temperature, while the second traces an arbitrary curve and is so connected that its millivoltage is opposed to that of the first couple by means of an automatic switch operated by the clock mechanism.

On a rising temperature, steel has a tendency to absorb heat during the change in its molecular structure and on a falling temperature to give up heat. These transformations are termed respectively the decalescent and recalescent points.

The first couple is embedded in a sample of steel to be tested shaped to a size about 1-inch long by -inches diameter, with a hole in one end ⅝-inch deep by 7/32-inch diameter. The second couple is embedded in a nickel alloy or neutral body of similar size which has no transformation point. These are placed together in a small electric furnace and brought to heat.

The thermocouple millivoltage varies with temperature of the body in which it is embedded, hence, there is a sharp deviation in the curve of the neutral body couple where the transformation points occur. The true transformation temperatures are read from the curve of the test couple at the time when the deviation starts on the curve of the neutral body couple.

This instrument can readily be equipped with an automatic cutout, adjusted to open the furnace circuit when a given temperature is reached, thus

permitting the entire test to be run off automatically when once set in operation. With an instrument of this type, the manufacturer can provide specifications as to the most desirable heat treatment for steel of a given composition.

In all heat treating work, pyrometers are of material aid to efficient operation, for with them the operator can intelligently follow the steel manufacturer's specifications and at the same time save fuel consumption and upkeep of the furnaces.

From the standpoint of fuel saving alone, pyrometers should save sufficient to more than warrant the installation, for the tendency without a gage is to operate at higher temperatures than necessary. An installation costing $600 requires a saving of but $10 per month, or as small an amount as 40c per working day to return 20 per cent on the investment.

Many firms have the mistaken idea that a pyrometer will prove a cure all for the ills of the heat treating department and that when once installed it requires no further attention. Pyrometers have limitations which should be recognized, hence, their use should be seasoned with judgment, for like the steam gage on a boiler, they but guide the operator to more efficient use of his equipment.

Plants having pyrometer installations of any size, should assign an intelligent man to complete charge of the equipment, for in case of necessity, it is desirable to have available one familiar with the apparatus rather than to leave such a matter to chance. Instances are numerous where a man unfamiliar with the equipment has taken the instruments apart and caused considerable trouble, the original difficulty being nothing more serious than a burned out thermocouple or loose connection. To prevent such tampering it is customary to seal instruments as they leave the factory.

To render prompt assistance in case of need, a service department is maintained by one of the instrument companies with traveling representatives attached to the district offices. When help is requested, these men call at a client's plant and check the pyrometers, making suggestions as to their efficient use. Some clients arrange with this department for periodic inspection and check of their equipment, and where the size of their installation does not warrant training one of their own men, this is recommended as good insurance. Where the installation is of sufficient size, the instrument companies are pleased to train at their factory, men assigned to care of the pyrometers, no charge being made for this service.

Standard checking equipment consists of a small electric furnace with rheostat control, a double scale portable instrument having a range of 20 and 40 millivolts, or equivalent in degrees, a thermocouple of platinum rhodium, a secondary standard couple of base metal and a switch.

The electric furnace should be some 12 inches deep and of sufficient diameter that several service couples at a time, removed from their protecting tubes, may be heated with a secondary standard yet kept equidistant from the furnace walls. Care should be taken that the hot junctions of the couples are together, and that they extend 6 or 8 inches into the furnace to prevent loss of heat by conduction.

The electric furnace, when brought to the temperature desired, should be held constant at that point for some minutes before readings are taken. It is desirable that a check be made at or near the normal operating temperature

of the service couples. The switch will enable quick connection of any thermocouple with the checking instrument.

In place of an electric furnace for standardizing the thermocouples, some prefer a small crucible of pure salt or pure metal. Pure salt is obtainable at any chemical supply house and should be raised to a temperature of about 1550 degrees Fahr. before inserting the thermocouples. There is a noticeable lag when the salt solidified or freezes, and the pyrometer should then read 1474 degrees Fahr. Tin, zinc, antimony, silver, copper and gold may be used for this work, their melting points being respectively 450, 787, 1166, 1761, 1981 and 1945 degrees Fahr.

Frequently equipment which works out well on laboratory tests requires alterations to meet service conditions. An instance of this kind is the disk chart recorder, in which the galvanometer system is mounted on the door of the case and swings away from the chart when the door is opened. It was found in service that the operator, when replacing the chart, often opened the case but 90 degrees, with the result that his sleeve engaged with the stylus, unbalancing the entire system and entailing considerable repair work. This trouble has been largely overcome by hinging the door at the left instead of at the right side.

In developing apparatus for measuring temperature, as in all lines of progress, one improvement merely paves the way for other refinements not previously foreseen and perfection lies just a step in advance. In this development work, it is largely men in the heat treating field who must be thanked for co-operation in working out the problems as they arise.

HIGH CARBON OPEN-HEARTH STEEL VERSUS CRUCIBLE TOOL STEEL IN THE MANUFACTURE OF MISCELLANEOUS TOOLS

By George Porteous*

(Paper presented by Title at Philadelphia Convention)

This subject should be of general interest because of the fact that the purchase of tool steel for general tools, such as hand and pneumatic chisels, shear blades, etc., is a large item in the yearly expense bill of many manufacturing establishments. The substitution of high carbon open-hearth steel in place of the more expensive crucible tool steels in the manufacture of these classes of tools is not a recent departure from established practice, but this subject in the past has not received the serious consideration which it merits.

It is axiomatical that the quality of open-hearth high carbon steel can not be compared fairly to that of the more carefully made electric and crucible tool steels, therefore, it is obvious that the forging and thermal treatment of the lower grade steel must be studied carefully in order to compete against the higher grade steels in the manufacture of miscellaneous tools.

I have before me several publications showing advertisements of special tool steel made into punch and chisel form, driven through steel blocks of from 1 to 2½ inches thick. This illustration purports to show that the steel from which the punches and chisels were made is of special quality and far ahead of any ordinary tool steel on the market. As a matter of fact, this is not a quality test at all, a sample of high carbon open-hearth steel can

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be made into a similar punch to that shown in the illustration, treated and drawn through a 3-inch block of medium carbon steel. An example of this is shown in Fig. 2.

From the foregoing example, we learn that high carbon open-hearth steel can be so treated that it will equal the durability of a so-called superior grade of steel by means of careful and intelligent treatment, and we can also realize that this characteristic also opens up a very large field of usefulness by the substitution of this steel in place of the high grade steels in the manufacture of many kinds of tools.

We have been using high carbon open-hearth steel as a substitute for tool steel for several years and we have been successful in its treatment for such tools as cold chisels, rivet snaps, punches and dies, taps, shear blades, and similar tools. The grade of steel that has proven most successful in the

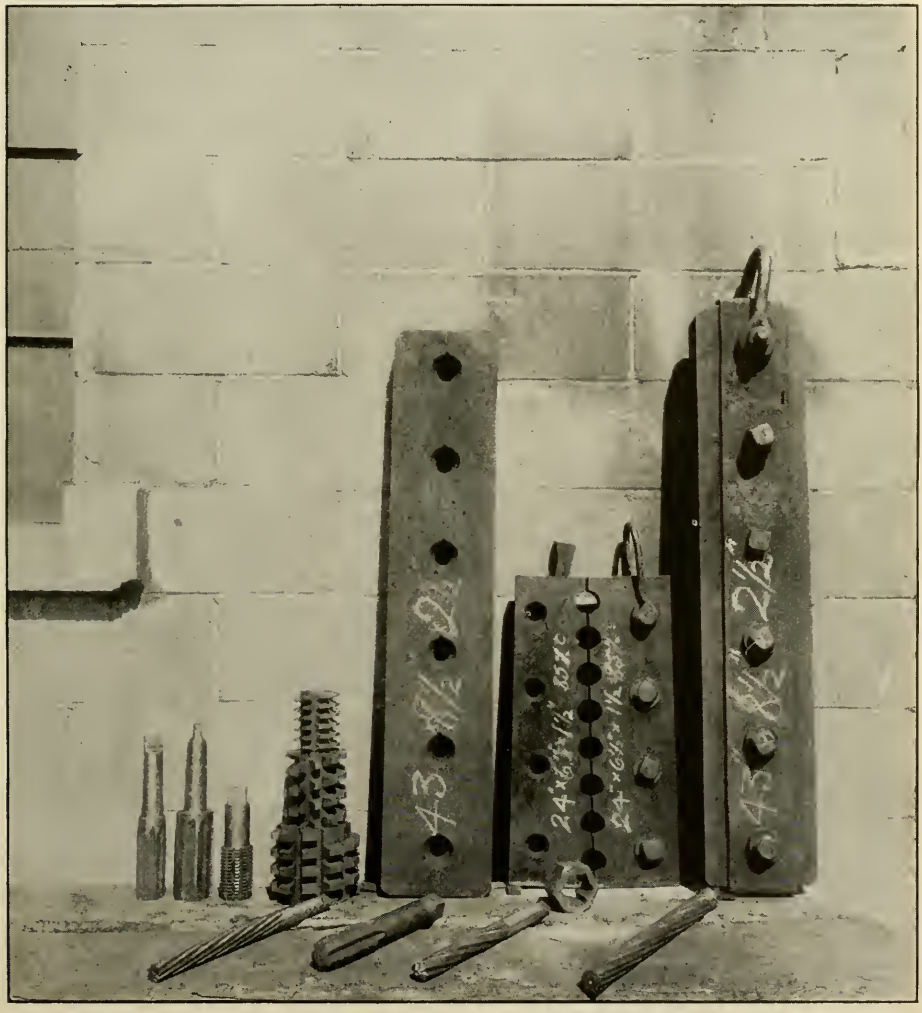

Fig. 1—Several Types of Tools Made from High Carbon Open-Hearth Steel

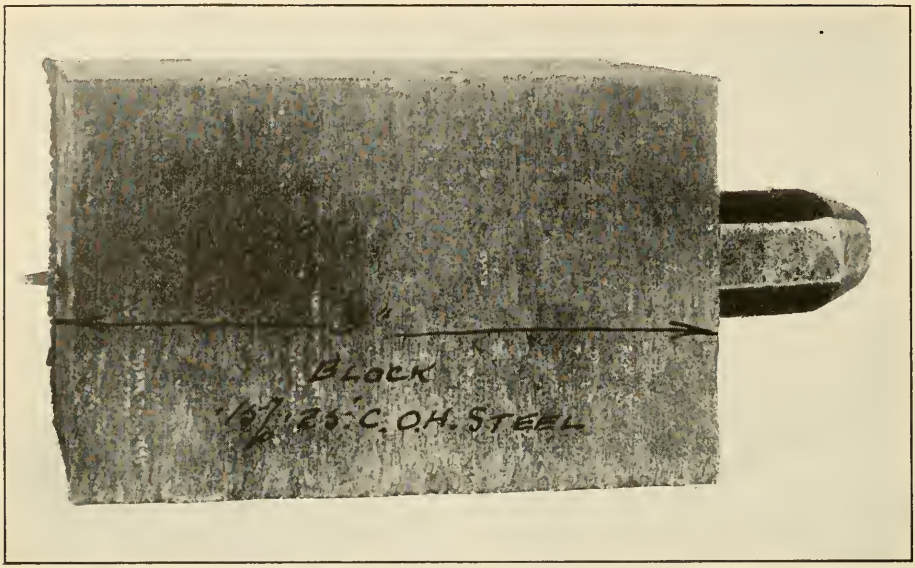

Fig. 2—Punch Made from High Carbon Open-Hearth Steel Piercing a 3-Inch 0.15-0.25 Per Cent Carbon Open-Hearth Steel Block

manufacture of these classes of tools has had an analysis of approximately 80 to 100 per cent carbon, less than 0.03 phosphorus, less than 0.03 per cent sulphur and 0.35 to 0.45 per cent manganese.

To get the best results for a steel of the above composition, great care is necessary in the heating and forging operations as well as in the subsequent thermal treatment. The billet from which the steel is drawn down should be at least twice the diameter of the finished forging. For example, ¾ to 1-inch octagon should be forged from not less than a 1½-inch bar or billet. The forging temperature should be from 1800 to 1950 degrees Fahr., reheated as required depending upon the rapidity of the forging operation and the dimensions of the finished bar. As the forging approaches the final stages, the hammering should become more rapid with lighter blows to finish the forging of the steel at a temperature of about 1350 degrees Fahr. which refines the grain and leaves the steel in better condition for the subsequent heat treatment.

The refining and equalizing process of steel treatment as applied to the forge and heat treatment of percussion tools such as cold chisels, hand and pneumatic, made from open-hearth high carbon steel is applied to the steel in several progressive stages, the success of each stage of the treatment depending upon the proper carrying out of the preceding one.

The first stage in the evolution of a cold chisel is the forging operation which in order to ensure success in the finished product must be done intelligently and with due attention to the proper forging temperature. The steel should be heated high enough to be in a thoroughly plastic condition, approximately 1850 to 1950 degrees Fahr. The closer the heat is to the higher temperature the better, so long as a reducing and not an oxidizing heat is obtained. At this stage it is well to remember that when forging the point of a chisel, the edges should not be hammered after the point has been

forged thin, because if the steel has been thoroughly worked down to a thin edge on the flat and then turned up and hammered on the edge, the force of the hammering will affect the grain of the steel on the edges but will not penetrate to the center, thereby causing the grain structure of the steel to be uneven. This will cause the steel to develop water cracks when hardened.

The proper method of forging the point of a chisel is to work the steel down to a square taper, as in the forging of a diamond point chisel and then flatten out to the desired width. A little practice will enable a person to gage the amount of stock required to forge the point of the chisel so that there will be little, if any, grinding to do on the edge. The rough point of the chisel should be trimmed off with a hot chisel immediately following the forging operation when the steel is at a cherry red heat. If necessary the chisel should be reheated.

The second or refining stage of the treatment is done by light blows with a hand hammer, the face of the hammer being dipped in water once or twice during the operation, on the flat of the chisel point when at a dark blood red heat.

The third stage of the treatment is the equalizing of the steel at the point of the chisel. The steel should be allowed to cool down to about 750 degrees Fahr., when the red disappears in the dark, dipped in black oil, withdrawn, and allowed to cool down slowly to atmospheric temperature. The oil should be at a temperature of about 125 degrees Fahr. for this purpose.

If the forging, refining and equalizing operations as just explained have been followed carefully, the grain structure of the steel will be in a state of equilibrium and in perfect condition to be hardened and tempered.

The hardening temperature should be the lowest possible consistent with the holding of the martensitic condition of the structure when heated over

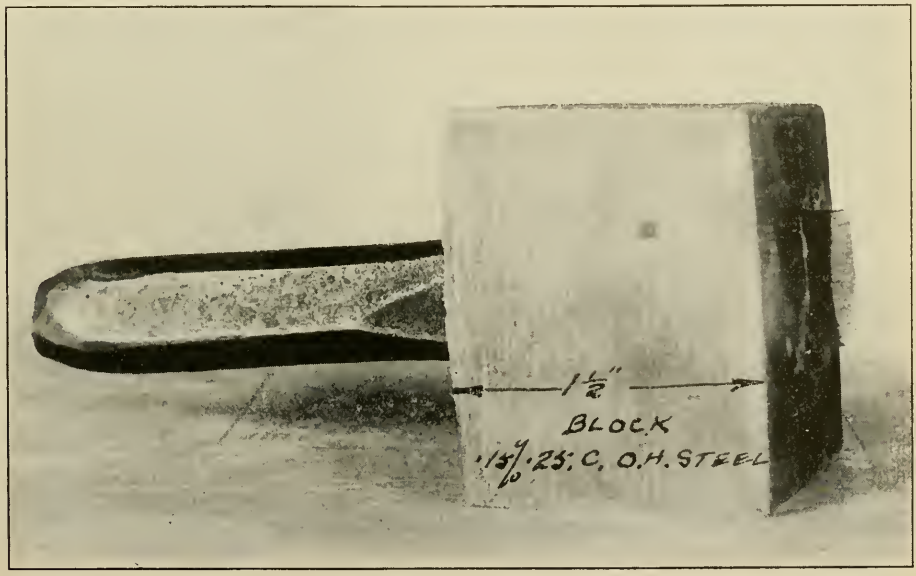

Fig. 3—Chisel Made from High Carbon Open-Hearth Steel Penetrating a 1½-Inch 0.15-0.25 Per Cent Carbon Open-Hearth Steel Block

the decalescent point of the steel. This would be about 1425 degrees Fahr. The point of the chisel should not touch water after the first chill. Check the rising temperature in oil when drawing temper by the color method. If an oil tempering bath is used, the temperature for this class of tool would be 490 to 500 degrees Fahr. for a period to be determined by the character of the work to be performed.

In cases where the structure of the steel at the points of cold chisels and kindred tools has been impaired by reason of overheating or cold working, it is possible to restore the steel to its original state by upsetting and rewelding the part affected, using a flux of common dry yellow clay. This flux prevents the atmospheric oxygen from finding its way through the pores of the metal and combining with the carbon, forcing the crystalline grains apart, and destroying their cohesion when heating the steel to the high temperature necessary. This, with the subsequent thorough hammering and working, will restore the steel to its original state. The shanks of pneumatic chisels are treated by being heated to 1450 degrees Fahr., dipped all over in cyanide of potassium, and cooled in oil with no further treatment.

Many of our scientific steel experts will be shocked at the crudity of the above treatment, nevertheless, it is the only treatment that gave maximum service on the shanks of chisels used by us for the chipping of hard steel billets.

The adaptability of using high carbon open-hearth steel in the manufacture of pneumatic chisels for chipping hard steel has been tested very thoroughly in the chipping and dressing of shell steel bars and billets. We have tested it against some of the more expensive steels on the market and it has given us just as good service as these high grade steels and as a consequence, we have adopted high carbon open-hearth steel exclusively for this class of tools.

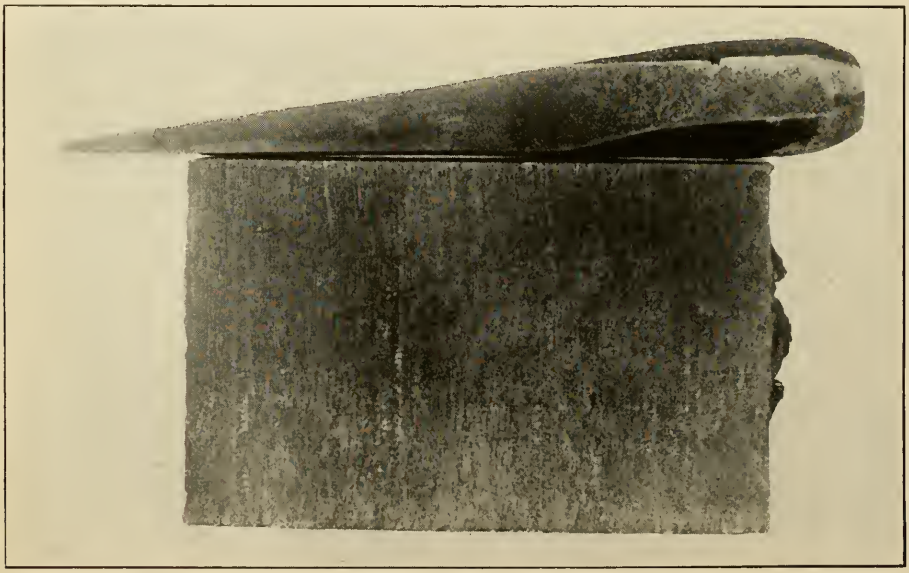

Fig. 4—Chisel and Block Are Both Made from the Same Material, High Carbon Open-Hearth Steel. The Chisel Has Had Special Heat Treatment

The approximate analysis of open-hearth high carbon steel for taps and reamers should be approximately the following: 0.90 to 1.10 per cent carbon, not over 0.02 per cent phosphorus, not over 0.02 per cent sulphur, and 0.25 to 0.35 per cent manganese. The steel should be forged at a temperature of 1750 to 1900 degrees Fahr. annealed at 1425 to 1475 degrees Fahr. in a muffle furnace or in covered receptacle to prevent access of air, or withdrawn when the proper temperature has been reached and covered with dry lime or ashes.

When the tools have been rough machined they should be equalized as described in a former paragraph. This equalizing process acts as a preventive to the warping of the tools in the subsequent heat treatment. The hardening temperature of this grade of steel is 1400 to 1425 degrees Fahr. To obtain maximum cutting qualities combined with toughness and resistance to shock, the best method of hardening treatment is to hold the tap or reamer in the water just long enough to harden the teeth or cutting faces and then immerse quickly in oil and allow the center of the tool to cool down slowly. The oil immersion allows the hard surface of the tool to heat up enough without losing hardness to take care of the cooling strains which would be liable to crack the tool if allowed to cool off entirely in the water. The drawing temperature is from 400 to 425 degrees Fahr.

The analysis of high carbon open-hearth steel found to give the best results in the manufacture of shear blades for cutting cold metal such as steel plate and bar stock is within the following limits: 0.85 to 0.95 per cent carbon, not over 0.03 per cent phosphorus, not over 0.03 per cent sulphur, and 0.30 to 0.45 per cent manganese. Steel that has been forged for shear blades should be annealed at 1450 to 1500 degrees Fahr., heated evenly in a muffle furnace and allowed to cool down with the furnace.

The hardening temperature is 1425 to 1450 degrees Fahr., chill in water

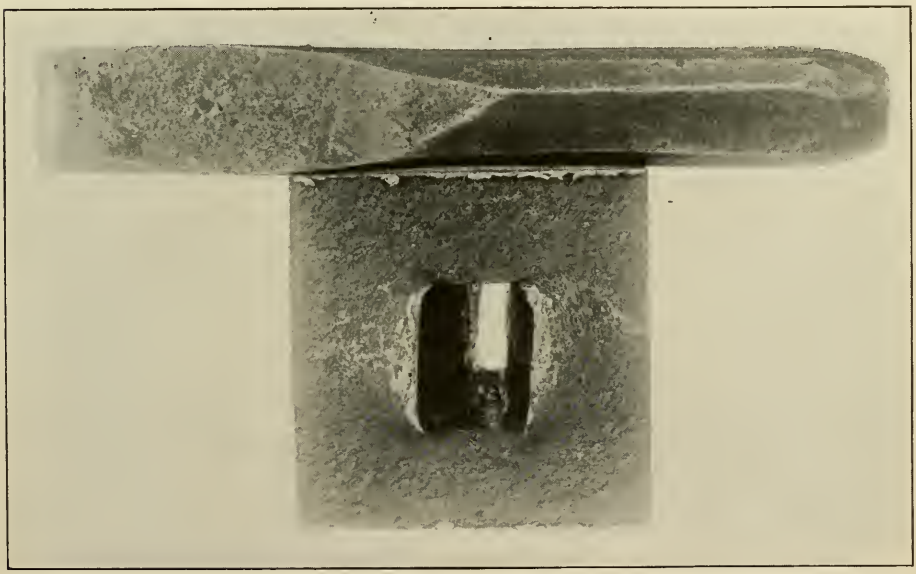

Fig. 5—End View of Steel Block Showing the Clean Cut Hole Made by Driving the Chisel Through It—This Is the Same Block Shown in Fig. 4

and allow to remain in the bath long enough to harden the exposed surfaces, then transfer to an oil bath and allow to cool down in the oil, draw in oil tempering furnace to 490 to 500 degrees Fahr. Allow the blade to remain in oil tempering furnace long enough to ensure thorough toughening. A shear blade of the following dimensions, 1½ x 7½ x 24 inches, should be allowed to remain at the proper drawing temperature for a period of at least two hours. To secure the best results in service from a high carbon open-hearth shear blade, the center of the blade longitudinally through the hole centers should be left as soft and tough as possible by being protected from the action of the quenching medium. This can be done by putting a bolt through each bolt hole with a washer on each side of the blade and the bolt and washer luted with clay. In the case of large size shear blades, the best method is to use two flat strips ⅜-inch thick and of suitable width, drilling holes in the strips to match the holes in the shear blades, luting with clay and holding them in place with suitable bolts. Care should be taken that the strips do not cover the cutting edge of the blade. In the case of a shear blade 9 inches wide, the strip should be 4½ inches wide. We have never had a shear blade to break either in hardening or in service when protected in this manner.

I have already mentioned in an earlier paragraph that the punch test is not an indication of the superior quality of the steel from which the punch is made, but is rather a problem in heat treatment. This drive test can be made by using either open-hearth high carbon or regular crucible tool steel. The analysis of the high carbon steel punch shown in Fig. 2 is as follows: 1.03 per cent carbon, 0.27 per cent manganese, 0.013 per cent phosphorus, and 0.032 per cent sulphur. The block through which the punch is driven is made of open-hearth steel of 0.15 to 0.20 per cent carbon. The punch is exactly as it was after being driven through the block, it has not been touched up in any way, the chisel which is driven through the 1½-inch steel block is taken from the same bar that the punch was made from. A chisel is much harder to drive by reason of the difference in the size and shape of the point and the finer the point of the tool the easier it is to drive.

High carbon open-hearth steel can not be made to take the place of high grade crucible steels for certain classes of tools such as some forms of milling cutters and intricate blanking dies because the cost of the workmanship in making and finishing these classes of tools overbalance the first cost of the steel to such a large extent that it would not be justifiable to use anything but the very highest grade of special alloy steel in their manufacture, but high carbon open-hearth steel can be used in the manufacture of tools some of which I have enumerated, and will give just as much satisfaction in service as the higher grade steels. There is another point in favor of the use of open-hearth high carbon steel as against the crucible steels and that is the difference in price. The cost of open-hearth steel is around 3 cents and crucible steel from 12 to 17 cents per pound. This considerable difference in price should be an incentive to the more general use of open-hearth high carbon steel.

I have investigated this matter thoroughly and I can guarantee that just as good results can be secured by the judicious use of open-hearth high carbon steel with the proper heat treatment as can be secured from the use of a higher grade and more expensive tool steel.

ROLE OF THE METALLURGICAL LABORATORY IN RELATION TO INSPECTION

By Marshall Medwedeff*

(Presented by Title at Philadelphia Convention)

What should be the relation of the metallurgical laboratory to the operating organization in general and to the Inspection Department in particular? A number of modern organizations have answered this question satisfactorily and have delegated to the metallurgical department such functions as properly lie within the scope. But it is for the benefit of such organizations in which the metallurgical department or laboratory is still groping to find its place and maximum usefulness, that this paper is intended. Heat treaters are familiar with the unenviable place the laboratory occupied until very recently and it is owing largely to the automotive industry that the metallurgical laboratory in particular has acquired the importance it possesses today.

The maximum usefulness of the metallurgical department in an organization will depend upon several factors: The support and confidence of the management; the co-operation and non-prejudice of the operating department to what they often term "the white collared force" and last but not least, upon the practical experience and level-headedness of the metallurgist in charge.

It is one of the unfortunate handicaps of the metallurgical fraternity that concerns wishing to be up-to-date secure a so-called metallurgist either just out of college or one with very little practical experience, who neither has the accumulated knowledge of years of experience nor the mental balance acquired as a result of this experience to be of serious use. When all the factors mentioned above are positive, then the metallurgical department should be an asset to any organization and its activities reflect in a balance in the ultimate reckoning on the books of the company.

It was always within the scope of the metallurgical laboratory to test raw and finished materials. It made reports of its tests and there usually its functions ceased. Fortunately for industry, a broader spirit and a more liberal attitude has developed within the last few years toward the laboratory, until today it is called upon more and more to take an active interest in production and well-trained experienced metallurgists are called upon to take charge of heat treating and forging departments.

With the advent of high speed steel tools, the manufacturing of interchangeable parts, and the production of alloy steels, shop practice has been revolutionized. The manufacturing of interchangeable parts calls for rigid inspection and today we have well developed inspection departments frequently functioning separately from the production department and responsible to the management. The functions of the inspection department are inspection of raw material such as bars, forgings, castings, etc., inspection of the product through the various stages of manufacture and last of all, final inspection.

The metallurgical laboratory is interested, or should be permitted to be interested, in all these stages. The manufacturing organization through

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its engineering staff should look to the metallurgical laboratory to specify the materials to be used for manufacturing different parts, the condition of these materials in their raw stage, referring particularly to the machine ability as determined by brinnel and shore hardness numbers. The laboratory should set the limits for these numbers to be followed by the inspection department in routine inspection. The experienced metallurgist with his expert knowledge of the physical fitness of materials, correlating his metallurgical knowledge with good shop practice, should be the person best qualified to specify the proper hardness for materials which would machine well and at the same time enhance production. There has been and still is, much guess work in this matter and no attention is paid to this phase of the metallurgist's usefullness.

In inspecting raw materials such as forgings, castings, etc., the inspection department must see that these materials conform to the specifications for such materials developed in the metallurgical laboratory. When such materials are manufactured within the home organization, it should be the duty of the metallurgical laboratory to see that these materials are manufactured in accordance with these specifications. Whenever the inspection department reveals considerable variations from the established standards, the laboratory should be called upon to investigate the causes and remedy, if possible, the manufacturing conditions responsible for these variations.

In case such products are purchased from an outside manufacturer, any complaints on quality or physical condition of these materials should be turned over to the metallurgical department. The metallurgist should take up these cases with the proper authorities at the source of manufacture, as his familiarity with the technical details of the processes involved should enable him to deal intelligently in each case, and settle any controversies that might arise to the satisfaction of all concerned. He may, if necessary, suggest remedies or improvement in practice that would help materially in eliminating defective material or product not up to specifications.

Upon the metallurgist's advice the home plant should, whenever possible, put the material rejected through such processes as will make it serviceable, penalizing the original source by charging it up with the cost of the work, such as annealing in case material is too hard and unpracticable for good production, and reheat treating of forgings in case they are too soft. The above, of course, by mutual agreement of the contracting parties, is suggested as it saves freight charges as well as time.

Regarding the metallurgical laboratory's interest in inspection through the various stages of manufacture, the laboratory is not interested primarily in the rejection of machined parts due to careless workmanship or faulty layout except in a general way, but it should be decidedly interested where the bad workmanship is a result of the physical condition of the material or faulty tools. Whenever the inspection department is compelled to reject partly finished parts which in their judgment is not due to carelessness, the laboratory should be called upon to investigate the cause of the trouble. It might find that the material is either too hard or too soft, or tools too soft or made of unsuitable steel for the particular job, or badly heat treated. Such occasions are not rare in modern machine shop practice.

Finally, the laboratory's interest in final inspection extends only as far as the general appearance and final physical properties and to such mechanical

nonconformities as are traceable to the metallurgical operations through which they passed in the heat treating processes, such as distortion, shrinkage, cracking, etc. The laboratory should study all such cases with a view of eliminating or reducing the rejections due to the above causes. The laboratory should specify the final physical properties of the finished product wherever, owing to service requirements, such properties are important. It should cooperate with the inspection department in devising routine methods of inspection.

This outline is necessarily general in nature but I have endeavored to state briefly what the relations of the metallurgical laboratory and the inspection department should be in a modern organization. They should at all times work together in eliminating the scrap pile. The laboratory must be ready to unravel the ills that metal absorbs through the manufacturing processes, find the causes for these ills and remedy them whenever possible. The function of the two should at all times be mutually helpful and work in the final analysis for the common interest of the organization.

EFFECT OF PHOSPHORUS AND SULPHUR ON STEEL

By E. W. Rettew* and L. A. Lanning*

(Presented before Hartford Chapter)

Phosphorus

Phosphorus is probably the most injurious impurity found in steel with the possible exception of the occluded gases such as oxygen, hydrogen and nitrogen. In the rolling mill the phosphorus shows no evil effects, the heat required for rolling apparently overcoming its detrimental qualities. In tin plate bars a small amount is necessary to prevent the sheets from sticking together in the rolling.

The ill effects of phosphorus are very apparent when the steel is cold. It produces the phenomena of "cold shortness" or brittleness when cold either in hardening or annealed steels. This brittleness is especially noticeable when the steels are subjected to vibratory stresses or to shock. In the tensile test the ductility is very little affected when the loads are slowly applied. Experiments apparently have proved that in amounts up to 0.12 per cent, phosphorus increases the strength under slowly applied loads. Under shock, however, this material was a failure. The bad effects of phosphorus increase as the carbon content is increased due to the formation of coarse crystals which produce brittleness.

The phosphorus produces a phosphide of iron, Fe_3P, which forms a series of alloys with iron. The eutectic of the series contains 64 per cent of the phosphide or 10.24 per cent of phosphorus and is very brittle. A small amount of phosphorus will dissolve in the iron forming no brittle eutectic, but as the carbon is increased it precipitates the phosphorus from the solid solution into the brittle eutectic form. Thus the lower the carbon the more phosphorus which may be present without being seriously injurious, but with each increase in carbon the phosphorus must be correspondingly decreased to prevent the eutectic formation with its coarse crystallization and brittleness.

Phosphorus increases the tensile strength of steel somewhat as does

*New Departure Mfg. Co., Bristol, Conn.

carbon, but does not decrease the ductility as measured by the tensile test as rapidly as does carbon. Phosphoretic steels resist wear better than steels with a lower phosphorus, and high phosphorus is permissable or even desirable if the steel is to resist abrasion only and no shock or vibration is to be encountered. Phosphorus increases the hardness of steel without lowering the electric conductivity as much as other hardening elements. High phosphorus steels are often used for third rails of trolley systems because of this property.

High phosphorus steels, 0.13-0.20 per cent are used largely for screw machine products where shock strength is not a requisite as it gives excellent machining properties, producing clean, bright surfaces and increasing the tensile strength. Phosphorus increases the rigidity of steel, reducing the deflection, but is unfit for structural purposes due to its inherent brittleness. Phosphorus also increases the resistance of steel to corrison.

One per cent is considered high in a low carbon steel or a low grade steel, while 0.08 per cent is considered a good grade of low carbon steel. The higher carbon grades contain 0.04, per cent, or under, while in tool steel it is usually kept under 0.03 per cent. As a rule, the permissable percentage of phosphorus is inversely proportional to the percentage of carbon.

Carbonizing steels should be low in phosphorus when strong objects are desired. These pieces should be carbonized in raw bone, due to its high phosphorus content. In wrought iron a certain amount 0.10-0.15 per cent is permissible and even desirable, especially if the iron is to be used for structural purposes, as such an amount does not produce the coarse crystallization near welds and the carbon is low tending to add to the strength of the metal by replacing the carbon without brittleness when carbon is present.

Sulphur

Sulphur is present in steel in two forms, iron sulphide and manganese sulphide of which the manganese sulphide is the more common. The sulphide of iron is present when the sulphur is high and the manganese is low. The sulphide of iron is seldom present in commercial steels as the manganese is usually present in sufficient quantities to combine with all the sulphur present.

When present as iron sulphide the phenomena of "hot shortness" or brittleness when hot is produced. It causes the metal to crack, tear and check in the rolling or forging and heat treating. The iron sulphide is brittle at the forging heat because it is in the molten condition so that there is little cohesion between the crystalline grains causing them to rupture when stressed in the working. The iron sulphide spreads out in thin sheets between the grains thus causing dangerous zones of weakness when cold. Also fine cracks may be formed in the rolling which are imperceptible in the finished product but which are very dangerous in service.

Manganese sulphide usually segregates in the form of globules or drops and is not as dangerous as the iron compound. These drops are drawn out in the rolling into long fine lines. Manganese sulphide often segregates with phosphides or slag to form ghosts in which condition it is very detrimental to the quality of the steel, the ghosts being zones or lines of weakness. Manganese sulphide is plastic at forging or rolling temperatures and does not interfere with the working of the metal as does the iron sulphide. It has been found that properly made steels with as high as 0.50 per cent sulphur with 1.06 per cent manganese could be forged easily and that

in the direction of rolling the mechanical properties were not affected and the impact resistance was even greater than the low sulphur steels, Transversely the high sulphur steel was weaker. Ship and boiler plates are known to be weaker transversely when high sulphur than the lower sulphur steels.

The higher the sulphur the greater the susceptibility of the steel to corrosion as the sulphides readily oxidize into oxides and sulphuric acid with consequent increase in the corrosion. It is important to have a sufficient amount of manganese present in the steel to insure that all the sulphur is combined with the manganese. Further care must be taken, however, as the sulphur is liable to segregate with the formation of iron sulphide with its attending dangers. Hence, the necessity for requiring a low sulphur analysis.

In slowly cooled steel castings iron sulphide often segregates to the crystalline boundaries forming basis upon which the ferrite crystals grow, producing a weakened structure. This condition may be largely broken up by annealing above the critical range. Most structural steels permit sulphur up to 0.06 per cent when sufficient manganese is present. For the better grades of steel for tools, etc., the sulphur should be below 0.04 per cent due to the danger of segregation. Excessive sulphur 0.12 per cent, produces a fibrous structure and a free cutting steel.

Detection of sulphur inclusions may be made by polishing the specimen and spreading over the surface a piece of silk which has been dipped in a solution of hydrochloric acid and mercuric chloride and holding for about five minutes. The sulphur is attacked by the acid forming hydrogen sulphide which deposits on the silk as black sulphide of mercury. The degree of color and size of the deposits indicate the segregation of the sulphur. Photographic silver bromide paper will show the same results first dipped in sulphuric acid. Under the miscroscope iron sulphide is a pale yellow or yellowish brown while manganese sulphide is a dull grey or dove color. Deep etching may show the amount of segregation by the size and location of the pits.

RELATIVE ECONOMY OF OIL, GAS, COAL AND ELECTRIC HEATED FURNACES

By Seth A. Moulton* and W. H. Lyman**

(A Paper Presented by Title at Philadelphia Convention)

It would seem as if no more important subject, than that of fuel economy could be discussed at this meeting. America's crippled railroads are unable to provide adequate transportation for fuels. The prodigality of past generations has in a large measure exhausted, or seriously depleted, the natural gas supply in those sections of the country where this commodity has been discovered. Owing to the demands of labor, the lack of adequate car facilities and the general increase in the cost of operating industrial enterprises the cost of coal has soared so rapidly that the consumer is paying not less than double, ofttimes treble and sometimes four times the price which he paid in 1914. Most serious of all, the demand for gasoline, kerosene and fuel oil has so far outstripped the rate of oil production that the price of fuel oil has reached a point where its use is almost prohibitive. Even if a con-

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sumer could afford to pay the highest price for fuel oil, there is a grave question as to how long he would be certain of a supply, as the demand is fast approaching and will soon overlap the visible supply.

The average consumer has been astounded and angered at the attack made on his purse by the advance in all commodities and particularly by the enormous increase in the cost of fuel, which is the most essential commodity. The consumer is disposed to place the blame for the costs, which appear to him so excessive, upon everything but the true cause. The war was at first to blame, then the railroads came in for their share of denouncement; "profiteers" is a favorite word to apply when no other specific point of attack appears and there is always the labor situation as an excuse. The law of supply and demand seems to be lost sight of entirely, for upon careful analysis of the problem, it will be found that the ultimate consumer's demand is the major factor that regulates costs. There have been a few unheeded voices raised in the wilderness during the past decade that have prophesied the stringency which we are now facing. These expert engineers were, when listened to, branded as calamity howlers; for why should the consumer be disturbed, or worry, with $3.00 coal, 3-cent oil, 12-cent kerosene, and 18-cent gasoline?

For years European industrial experts and engineers have been astounded at America's waste. Abundant natural wealth, intensive quantity production with a home market that consumed the output of its factories have been America's salvation in the past. But, prior to 1914, the manufacturers had commenced to feel the pressure of European competition and when the reconstruction period has reached a stage of stabilization, America's markets will be invaded as never before and the American manufacturer will be passing through an era which may prove disastrous if he does not prepare now for the emergency. Waste must be reduced to a minimum and there is no other item where more lucrative economy can be attained than by fuel or heat conservation. This statement especially applies to the present average industrial furnace practice, meaning by the term "industrial furnace," those furnaces in which heat is directly utilized for process work in contradistinction to those furnaces in which heat is utilized to generate power.

Owing to the vast scope of the industrial furnace field, it is necessary to confine this paper to a concrete case covering some particular industry. The case selected is the one with which the writers are most intimately familiar and probably one which will have special interest to a large percentage of the audience. The principles involved will apply to a large majority of the industries where quantities of small parts are heat treated.

The premises are as follows: A factory produces per day of 24 hours about 30,000 pounds of gears. The gear blanks are delivered to the factory directly from the hammers in the forge shop. The gears consist of the usual transmission and differential gears, such as used in automobiles. The transmission gears are high carbon steel and the differential low-carbon carburized. The necessary heat treating equipment will consist of:

1. Annealing Furnaces .....1400-1600 degrees Fahr.
2. Carburizing Furnaces .....1700-1800 degrees Fahr.
3. Hardening Furnaces .....1450-1550 degrees Fahr.
4. Drawing Furnaces ..... 350- 650 degrees Fahr.

All of the forging blanks are annealed before machining; about three-quarters of the machined gears and parts are carburized, all the carburized gears are given a double hardening for core and case, all gears and parts are hardened and all parts are drawn.

The possible sources of heat supply and their values are as follows:

1. Oil ..... 140,000 b.t.u. per gallon
2. Natural Gas ..... 1,100 b.t.u. per cubic foot
3. City Gas ..... 650 b.t.u. per cubic foot
4. Water Gas ..... 300 b.t.u. per cubic foot
5. Producer Gas ..... 170 b.t.u. per cubic foot
6. Coal ..... 12,000 per b.t.u. pound
7. Electric Current ..... 3,412 b.t.u. per kilowatt hour

For the heat treatment previously specified only comparatively low temperatures are required. No difficulty will be experienced in attaining the desired maximum temperature of 1800 degrees Fahr. with any of the heating mediums above enumerated; but it should be noted that the producer gas with a b.t.u. of 170 per cubic foot and the electric current would require specially designed furnaces to obtain higher temperatures than 1800 degrees Fahr. The reason for this condition will be explained later.

As the economical utilization of the heat depends entirely upon the furnace design, it is necessary to describe the several types of equipment that are commercially available. Before describing the furnace designs and establishing their comparative merits, however, certain fundamental features that must be recognized in designing furnaces for any particular service should be enumerated.

The first factor to be taken into account is the probable flame temperature, or in other words the temperature of combustion that is to be derived from the burning of the fuel in a fuel-heated furnace. The second factor is the temperature required in the furnace working chamber. The third factor is the character and volume of material treated. The fourth factor is the cycle of the heating.

With the foregoing premises established, it is a comparatively simple matter to decide upon the general character of furnace design which will prove most economical in overall operating costs with a fuel at a given price.

Some criticism may be raised as to why the flame temperature is first recognized. There are important reasons for this course of procedure. The first reason is that we must ascertain whether or not the fuel or fuels under consideration can be made to yield the desired temperature. The second reason is that the maximum temperature which may be attained from a given fuel may be excessive and provisions then must be made to reduce this temperature, or provision must be made in the design of the furnace to withstand the excessively high temperatures.

After the first and second factors have been established, the important element affecting the general furnace design may be ascertained and this is the amount of heat which can be utilized effectively in the working chamber, taking into account the flame temperature and the temperature of the exhaust gases.

We will take as an example the specific case of a carburizing furnace having a working chamber temperature of 1800 degrees Fahr. heated with either oil, gas or coal fuel, with a heat cycle of eight hours

and a charge of 3000 pounds and of such dimensions that a working chamber 4 feet wide, x 6 feet long and 3 feet high is required.

The temperature of the exhaust gases at the outlet ports of the working chamber would be about 1900 degrees Fahr. This does not mean that there is an excessive temperature at the exhaust ports, but to allow for the losses through the walls of the furnace and maintain an interior temperature of 1800 degrees Fahr., the gases must be in excess of this temperature.

The theoretical flame temperature, or the combustion temperature, of oil with a theoretical air supply is about 5000 degrees Fahr. With this fuel we are immediately confronted with the problem of how we can overcome the destructive effects of this intense heat if the oil can be burned with theoretical efficiency? No refractory made will long withstand such a temperature and the best grade of ordinary firebrick would melt, especially under a load, at a much lower point. It is difficult to maintain furnace brickwork, particularly roof arches at temperatures in excess of 2500 degrees Fahr., but by proper distribution of the burners and with properly designed combustion chambers, it is possible to operate with oil flame temperatures around 3500 degrees Fahr. This means the admission of an excess air volume of 50 per cent more than the theoretical, if all of the carbon in the fuel is consumed. The generation of a smoky flame indicates that all the carbon is not consumed, and as the majority of oil-fired furnaces are so operated, it is quite likely that about 33 per cent excess air is used; or what is more likely if the burner discharges into a restricted area, the flame temperature is much below 3500 degrees Fahr., and usually more than twice the theoretical amount of air is admitted, reducing the combustion temperature to around 2500 degrees Fahr.

Assuming that the combustion chamber, the atomizing and the air mixing devices, or in other words the complete burner, is designed for securing a flame temperature of 3300 degrees Fahr. with a waste gas temperature of 1900 degrees Fahr., the approximate amount of heat wasted necessarily in the spent gases would be 1900/3300=0.57, leaving about 45 per cent of the heat generated available for useful work in the furnace chamber to be distributed in radiation through the furnace walls.

The heat required to bring the charge up to temperature will be approximately 3000 x 1800 x 0.17=918,000 b.t.u. and the heat lost through the walls of a properly constructed furnace of the dimensions given as indicated by tests will be 140,000 b.t.u. per hour, or for eight hours 1,120,000 b.t.u. This makes the total heat requirements in the chamber 2,038,000 b.t.u., but as only 43 per cent of the heat admitted in the fuel is available in the chamber, the amount of heat which must be admitted will be approximately 2,038,000/0.43=4,740,000 b.t.u. The amount of oil required per charge will then be 4,740,000/140,000=34 gallons. These figures are the very best results which we could expect to obtain in the commercial operation of an oil-fired carburizing furnace for the above-described service.

There can be no real comparison between the efficiency of furnaces employed on carburizing work and those used for heating only. Nevertheless, to demonstrate the important bearing which the character of the charge and the heat cycle has on furnace efficiency, we will assume that the furnace described is loaded with a charge of cast iron weigh-

ing 3000 pounds, so disposed that the heat can readily reach the entire charge and with the cross section of the pieces to be treated such that the full temperature of 1800 degrees Fahr. will be obtained in two hours.

The total heat required will then be 918,000 b.t.u. plus 2 x 140,000 b.t.u.=1,190,000/0.43=2,786,000 b.t.u. The fuel oil required will be 2,786,000/140,000=20 gallons. The relative efficiency of the furnace under the two cases will be as follows:

For carburizing 918/4,740 x 100=19.4 per cent.

For heating 918/2,786 x 100=33 per cent.

The preceding efficiencies never could be obtained in the ordinary commercial oil-fired furnace and probably could not be consistently maintained in a furnace of special design. The reasons are as follows: In our computations we have made no allowance for incomplete combustion and furthermore we have made no allowance for the heat lost in gasifying the fuel mist that is delivered at the burners or the heat value lost in the water vapor generated by combustion.

Reducing our flame temperatures to the practical work limits or from 2500 to 2700 degrees Fahr. the respective efficiencies for the two classes of service will be as follows:

For carburizing—2,038,000/(700-2500)=7,280,000 b.t.u.

Oil consumption=(7280-4740) x 34=52 gallons per charge.

Efficiency=100 (918,000-7,280,000)=12.6 per cent.

For heating—1,198,000/(700-2500)=4,280,000 b.t.u.

Oil consumption=4280/2786 x 20=30.8 gallons per charge.

Efficiency=100 (918/4280)=21.4 per cent.

Even these results are higher than would obtain under ordinary conditions because we have kept the furnace radiation losses at a low rate which could not be realized with a standard type of furnace. No allowance has been made for the heat lost in gasifying and in water vapor.

Numerous tests indicate that the usual oil-fired equipment used on the classes of service cited above have for carburizing an efficiency of about 5 per cent and for annealing from 10 to 15 per cent. Making due allowances for the losses from door openings and the almost certainty of improper combustion, the last cited figures can be relied upon as representing the best average practice.

It will be interesting for a few moments to analyze the above problems for the purpose of determining whether or not there can be made any material gain in economy. The heat distribution sums up as follows:

Carburizing—1st Case

Entering work	918,000 b.t.u.	19.4 per cent
Loss from Walls	1,120,000 b.t.u.	23.6 per cent
Loss from waste gases	2,702,000 b.t.u.	57 per cent
Total	4,740,000 b.t.u.	100 per cent

Annealing—1st Case

Entering work	918,000 b.t.u.	33 per cent
Loss from walls	280,000 b.t.u.	10 per cent
Loss from waste gases	1,588,000 b.t.u.	57 per cent
Total	2,786,000 b.t.u.	100 per cent

It is not necessary to review the second cases, which are closer to normal operating conditions, for the above are sufficient to indicate that the point where the greatest savings can be made is the utilizing the heat wasted in the flue gases. A very large percentage of the heat can be reclaimed by recuperation and returned as hot air to the furnace. But what will be the effect? The temperature of the flame will be increased and as we are already carrying that temperature up to, if not beyond the practical limits, there would be no appreciable gain from recuperation and the expense of such an installation is not justified. The only solution of the problem would be to burn the oil at nearer its theoretical temperature by reducing the volume of air and constructing a combustion chamber, outside the limits of the working chamber, which could resist the high flame temperature. Up to the present date this has not been satisfactorily accomplished, although numerous attempts have been made. We are, therefore, confronted with the inherent fault in oil fuel for furnace service which precludes its efficient use and consequently its economical use when a high price must be paid for the heat content in the oil that must be wasted.

As it is impractical to provide means which will make any material saving in the waste gas losses, the next and only means whereby a saving may be made is in the radiation losses. It has already been stated that the hypothetical furnace was provided with extra heavy insulation. By adding an extra 4-inch thick course of insulating brick the radiation losses can be reduced by about two-fifths. Hence, the total heat consumption can be reduced by about 16.7 per cent when the furnace is used for carburizing and about 7.1 per cent when the furnace is used for heating. The cost for the extra insulation will be approximately $1000 taking all factors into account. For furnace work we are justified in capitalizing an investment at 25 per cent allowing 15 per cent for fixed charges and maintenance and 10 per cent for apparent net profit. It follows that there must be a saving of 250 per year to justify the additional insulation cost. Assuming that the furnace is operated continuously for 300 days of 24 hours per day, the oil saving would be 3 charges x 34 gallons x 300 days x 16.7 per cent=5110 gallons=4.9 cents per gallon or more. We would be justified in incurring the extra insulation expense, if the furnace was to be used continuously for carburizing. With the furnaces used for heating, a saving of 5110 gallons of oil could be made under continuous operation, which checks the preceding figure.

The preceding discussion on the insulation savings brings out an important point which should be noted and this is that the heat cycle and character of the load combined with the hours of service per day have an important influence on the determination of the furnace design. The fallacy of attempting to utilize a stock pattern furnace for a diversified service without carefully analyzing its suitablity for the contemplated service is also self evident.

Without setting forth the detailed calculations; but proceeding upon the same basis of analysis as previously described and confining our conclusions to Case 2 as representing the best attainable practice, the following tabulation gives the fuel consumption and the efficiency of the four different classes of gas fuels.

Only one factor requires discussion in order that the efficiencies given in the tabulation may be understood. This is the factor that gas may be

more efficiently burned than solid fuels, either oil or coal. This is possible for two reasons: First, the flame temperatures for the complete combustion of gases are lower than for oil or coal; and second, that gas may be burned with approximately the theoretical volume of air required for complete combustion. By calculating the products of combustion, and by comparative tests, it can be shown that under commercial operating conditions producer gas is 15 per cent more efficient than oil, blue gas 30 per cent more efficient, city gas 35 per cent more efficient, and natural gas 50 per cent more efficient for furnace service at the temperatures under consideration.

The gas fuel consumption and the efficiencies for carburizing will then be as follows:

Producer gas	37.3 M cubic feet per charge	14.5 per cent
Blue Water Gas	18.7 M cubic feet per charge	16.4 per cent
City gas	8.3 M cubic feet per charge	17.0 per cent
Natural gas	4.4 M cubic feet per charge	18.8 per cent
For Heating		
Producer gas	22.0 M cubic feet per charge	24.6per cent
Blue water gas	11.1 M cubic feet per charge	27.6 per cent
City gas	4.9 M cubic feet per charge	28.8 per cent
Natural gas	2.6 M cubic feet per charge	32.0 per cent

The above efficiencies are admitted to be higher than would obtain in usual practice due to the heavy insulation conditions assumed as previously mentioned and also due to the fact that the load per square foot of hearth is the maximum that could be obtained under the most favorable conditions. A load of 2000 pounds would much more nearly represent average practice, but the high ratings herewith assumed were purposely selected to indicate the maximum limits of economy which might be secured.

To continue the comparison using coal as a fuel, it is necessary to modify our method of analysis because the design of coal-fired furnaces will be radically different from the oil or gas-fired. This necessary change in design will increase the radiation losses and there will also be losses in the ashes. Carrying out the computations with the above modifications yields results as follows:

Carburizing

Heat entering work	918,000 b.t.u.	8.4 per cent
Radiation losses	1,500,000 b.t.u.	13.7 per cent
Waste gas losses	2,418,000 b.t.u.	75.1 per cent
	[2700—1900] / 2700	
Ashes	320,000 b.t.u.	2.8 per cent
Total	10,968,000 b.t.u.	100 per cent

The amount of coal burned then will be 10,968,000/12,000=914 pounds per charge, or 3.3 pounds of charge heated per pound of coal.

Under actual working conditions the amount of gross charge treated per pound of coal from actual tests and records varies from 1.75 to 5 pounds, and for a heat cycle and load corresponding to the hypothetical case above cited, the actual test shows exactly the same production as that given by the above computations; 3.3 lbs. of metal per pound of coal.

For heating the following will apply:

Heat entering work	918,000 b.t.u.	15.75 per cent
Radiation losses	375,000 b.t.u.	6.45 per cent
Waste gas losses	4,370,000 b.t.u.	74.88 per cent
	1,293,000	
	800÷2700	
Ash losses	170,000 b.t.u.	2.92 per cent
Total	5,833,000 b.t.u.	100.00 per cent

The amount of coal required for heating only then is 5,833,000/12,000=486 pounds per charge or 6.2 pounds of metal per pound of coal. This result checks with actual tests and may be considered conservative.

An electric furnace of the metallic resister type might be employed for either the carburizing or the heating work. The economy of such a furnace would depend upon the cost of power.

As all of the losses from an electric furnace are by radiation, it follows that the use of extra heavy insulation is justified. Practice has demonstrated that for a furnace of the size under consideration, operating at 1800 degrees Fahr., the radiation losses will be not more than 30 kilowatts per hour. The heat and power requirements of such a furnace on carburizing will then be as follows:

Radiation losses 30K.W. x 8	240 k.w.hrs.@3412	b.t.u.	818,880	b.t.u.	47 per cent
	269 k.w.hrs.@3412	b.t.u.	918,000	b.t.u.	53 per cent
Total	509 k.w.hrs.	b.t.u.	1,736.880	b.t.u.	100 per cent
For heating Radiation losses 30 x 2	60 k.w.hrs.@3412		204,720	b.t.u.	18.25 per cent
	269 k.w.hrs. 3412		918,00	b.t.u.	81.75 per cent
Total	329 k.w.hrs.		1,122,720	b.t.u.	100.00 per cent

We can compile a tabulation from the preceding computations which will show the relative value of the several types of furnaces and heating mediums. The rates which prevail in a central western district for the several heat services are as follows:

1. Oil ..... 50 cents per gallon
2. Natural gas ..... 50 cents per thousand cu. ft.
3. City gas ..... 80 cents per thousand cu. ft.
4. Water gas ..... 40 cents per thousand cu. ft.
5. Producer gas ..... 10 cents per thousand cu. ft.
6. Coal ..... $6.00 per long ton
7. Electric current ..... 1⅛ cents per kilowatt hour

Applying the above values the accompanying Table 1, comparative operating costs has been prepared. The results shown on this tabulation indicate that, with the exception of natural gas, clean producer gas and coal are by far the most economical fuels to employ and that electricity, under the premises assumed is not economical. Like all figures pertaining to furnaces, these conclusions should not be given a general application. In most instances, it will be found that producer gas and coal are much cheaper than oil unless

oil can be purchased for less than 8 cents per gallon, but in many cases it will be found that electricity can compete with almost any class of fuel if power can be purchased at a reasonable price and the service is such that the benefits derived from the highly efficient electric furnace can be utilized advantageously.

The hypothetical cases assume a character of loading which does not demand accurate temperature control. We have also assumed that the fixed charges for the electric furnaces would be the same as for the fuel-fired furnaces. This is not true as the electric furnace will have double the life of the fuel-heated. We have also assumed the labor element would be the same for the fuel furnaces, with the exception of coal, as for the electric. This is not true because if the high economy is to be secured particularly from oil-fired equipment, very skillful attention will be required and the cost for operating labor on the fuel-fired equipment will be much more than for the electric furnace.

TABLE I
Comparative Operating Costs

No.	Class Fuel	Fuel per charge	Fuel cost	Installation cost	Efficiency per cent	Operating costs: Fixed charges	Extra labor	Heat	Total per charge	Cost per pound	Saving over oil: per charge	per cent
	CARBURIZING											
	1	2	3	4	5	6	7	8	9	10	11	12
1	Oil	52 gal	15c	$2400	12.6	$0.40	....	$7.80	$8.20	$0.00274	....	..
2	Natural gas	4.4 M	50c	2400	18.8	0.40	....	2.20	2.00	0.00087	5.60	68
3	City gas	8.3 M	80c	2400	17.0	0.40	....	6.64	7.04	0.00235	1.16	14
4	Water gas	18.7 M	40c	2400	16.4	0.40	....	7.48	7.88	0.00263	.32	3.9
5	Producer gas	37.3 M	10c	2400	14.5	0.40	....	3.73	4.13	0.00137	4.07	50
6	Coal	914 lb.	6.00	3600	8.4	0.60	$1.20	2.45	4.25	0.00140	3.95	48
7	Electricity	500 K.W.H.	1½c	9000	53	1.50	....	7.50	9.00	0.00300	0.80	9.7
	HEATING											
1	Oil	30.8 gals	15c	2400	21.4	0.10	....	4.62	4.72	0.00157	....	..
2	Natural gas	2.61 M	50c	2400	32.0	0.10	....	1.30	1.40	0.00047	3.32	70
3	City gas	4.9 M	80c	2400	28.8	0.10	....	3.92	4.02	0.00134	0.70	14.8
4	Water gas	11.1 M	40c	2400	27.6	0.10	....	4.44	4.54	0.00151	0.18	3.8
5	Producer gas	22.1 M	10c	2400	24.6	0.10	....	2.21	2.35	0.00078	2.37	50.3
6	Coal	486 lb.	6.00	3600	15.75	0.15	$0.30	1.30	1.75	0.00058	2.97	63
7	Electricity	329 K.W.H.	1½c	10500	81.75	0.44	....	4.94	5.38	0.00179	0.66	14

Cost of oil and gas-fired furnaces installed $100 per square foot of hearth
" " coal-fired furnace installed 150 " " "
" " electric furnace 100 kilowatt capacity installed $90 per kilowatt
" " " " 150 " " " 70 " "
Output 3000 pounds charge—8 hours heating and carburizing, 2 hours heating only
Fixed charges including interest, depreciation, taxes, insurance and maintenance 15 percent
Extra operating labor for coal-fired furnace 60 cents per hour, one man 4 furnaces
Annual service 7200 hours

There is another very important feature in connection with the installation of electric furnaces that must be taken into account and this is the increased load and higher power factor occasioned by the furnace load. To illustrate: Suppose a factory having electric furnaces of the character considered in the tabulation, has an average load of 100 kilowatts for 20 hours, or a power consumption of 2000 kilowatt hours per day and that the rate for this power is 2 cents per kilowatt hour or a total of $40 per day. Assuming that two furnace units are required for carburizing, the heating power will be 3 x 2 x 500=3000 kilowatt hours per day. The addition of this power under the average system of rate scheduling should reduce the cost for all the power to 1½ cents per kilowatt, making a saving of $10 per day which should be deducted from the furnace power. With the charges per day as have been assumed in all the preceding computations, there will

be a saving per furnace charge of $10/(3 x 2)=$1.67. Subtracting this amount from the cost in Table 1 of $9.00 for electric carburizing makes the cost $7.33, showing a saving of 77 cents per charge, or a gain of 9½ per cent by the use of electric furnaces.

When complete heat treating plants are electrified, or when large furnace units of the resistor type are installed in connection with an industry of average character, usually it will be found that the saving in the mill power cost will justify electric furnace equipment.

The authors do not purport to claim that the accompanying methods of determining furnace economy are scientifically accurate, because they fully appreciate that the chemical composition of the fuel and the escaping gases must be analyzed to solve with minute accuracy the actual furnace efficiency; but the results as derived by the methods employed are found to check with actual tests and they are accordingly sufficiently accurate for all practical purposes.

Applying the general methods of deduction which have been employed in the general discussion which precedes to the specific case of a gear plant producing 30,000 pounds per day of 24 hours with specifications as cited at the introduction of this paper, we must first select the possible combination of equipment that may be employed.

For annealing forgings that will produce 30,000 pounds of finished gears about 40,000 pounds of blanks must be treated. Two methods may be employed for annealing. First, the blanks may be placed loose upon the furnace hearth and second, the blanks may be packed in boxes. In the first case, the blanks will be allowed to cool in the furnace and in the second case the loaded boxes will be transferred to a cooling chamber. The second system is far superior to the first on account of the fact that the furnace working chamber will be kept up to temperature and the blanks being packed in boxes and cooled in a chamber free from circulating air will be cooled more uniformly and with less scale. Thus economy of fuel and high quality of product will be obtained. The heat cycle for this class of work is usually from 6 to 8 hours up to the temperatures of 1550 degrees Fahr. the material being left in the cooling chamber for approximately the same time as it is retained in the furnace. If no cooling chambers are used, the material is usually allowed to cool in the furnace to 600 to 800 degrees Fahr. or from 2 to 4 hours.

As a slow anneal appears to produce more satisfactory results, we will employ a heat cycle bringing to heat in 8 hours, cooling in air 3 hours, and in chambers 8 hours.

Actual practice has demonstrated that the weight of boxes to charge for annealing work is from 25 to 30 per cent and that loaded boxes, resting upon special rail and ball races and weighing about 2100 pounds can be handled conveniently. With 28 per cent of the weight tare, the net weight per box will be 1500 pounds. For 40,000 pounds per day, about 27 boxes will be required, or for an 8 hour heat cycle, 216 box hours. An economical size of furnace to handle these boxes will have a hearth about 4 feet wide x 7 feet 6 inches deep and 3 boxes can be accommodated per charge. A furnace of this size will handle 9 boxes per day, hence 3 chambers will be required for heating and three for cooling. These 3 working chambers can be built in a single battery or two batteries of two working chambers each may be employed leaving one chamber as spare.

With the heat cycle specified and with coal-fired furnaces of the di-

mensions described, the actual fuel consumption in commercial operation has an average of about 20 pounds of metal gross, or about 14 pounds of metal net per pound of coal having a heat value of 14,000 b.t.u. per pound. Such furnaces then show a commercial efficiency of approximately [(20 x .17 x 1550)/14,000] x 100=37.6 per cent gross, of 27 per cent net. Reverting to the Table I under line 6, column 5, for coal fired heating it will be observed that for the 2-hour cycle heating only without cooling that the efficiency is only 15.75 per cent. If the cooling were accomplished in the working chamber this efficiency would drop to less than 12 per cent net. Again referring to Table I, line 6, column 10, the price per pound for heating is 0.058 cent, which will be increased by cooling to not less than 0.075 cent.

There would be required at least six chambers 4 x 6 feet to anneal and cool the work in the working chambers. These would cost, as shown in Column 4, Table I, 3600 x 6=$21,600. The two twin-chamber units with cooling chambers would cost $13,500 each or $27,000, making an increased investment of $5400. The annual saving with cooling chambers would be 0.075 cent—0.058 cent x 40,000 pounds x 300 days=$3240 per year. Hence the investment value would be $3240/$5400=60 per cent. Taking into account the cost for annealing boxes and their depreciation, it is safe to state that the cooling chamber type of furnace would pay for itself in two years.

It is a simple matter to ascertain what the relative economy would be approximately with the other types of fuels by using the comparative efficiencies given in Table I.

For carburizing units to treat 75 per cent of 30,000 pounds, or 22,500 pounds of gears per day, if the gears are packed in cast alloy steel boxes with the net weight of the material treated about 33 per cent of the gross weight of the charge, there will be required eight chambers about 4 feet x 7 feet 6 inches. The above ratio of net to gross charge corresponds with good average practice. If high grade and expensive alloy boxes are employed it is possible to make the net weight about 50 per cent of the gross, but for the purpose of this paper the more usual conditions have been assumed.

Any of the heating mediums may be used in connection with the carburizing units. Under normal service it is not to be expected that the high efficiencies shown in column 5, Table I will obtain. From actual tests on well designed and operated equipment it has been found that 10 per cent efficiency represents about the best results that may be expected for carburizing work requiring a heat cycle of from 8 to 10 hours. In the comparative statements which follow later 10 per cent is the efficiency which has been employed for oil fuel prorated for the relative efficiency of the other classes of heating elements.

Several methods may be employed for hardening as follows:

1. Lead pots, oil or gas-fired.
2. Plain box type furnaces, lot charged,
   Oil or gas-fired or electrically heated.
3. Continuous furnaces, gas or electric heated.

It will probably be noted quickly that coal has not been considered as a possible fuel for the hardening furnaces. Coal-fired furnaces are undoubtedly the most economical type that can be employed, except when

an abundant supply of natural gas is available at a reasonable cost, but it is not a fuel that can be used efficiently on short heat service when accurate temperature control is essential. For annealing, carburizing, or any work requiring long soaking heat, especially when the size of the installation and the correlated service demands do not justify the expense of a gas producer installation, coal should always be given serious consideration.

It will also be noted that electricity has not been considered as a possible heating medium for the lead pots. This is due to the fact that the metallic resistor type of furnaces is the only one which has yet been developed to a point of certain economic application for heat treating work. This fact, combined with the limits of temperature, 1900 degrees Fahr. at which the metallic resistors may be operated, preclude the use of the electric-heated lead pots, on account of the transmission drop between the temperatures of the heating elements and the lead bath. At least 500 degrees Fahr. should be allowed for this drop, which means that the lead bath could not be maintained at a higher temperature than 1400 degrees Fahr. If heavy charges are immersed in the lead it is more than probable that even 1400 degrees Fahr. could not be maintained uniformly. At the present state of the art this is too close a working margin, thus conservative engineering necessitates disregarding electric heat for pot hardening. This subject should not be summarily dismissed without mentioning the fact that designs are now being prepared and tests are soon to be carried out on a new form of electric heated pot hardening furnace. The results of these tests may reverse the conclusions above set forth.

One more fact may be noted which is that oil has not been included as a heating medium for continuous furnaces. The manufacturers and advocates of oil fired equipment we are sure will take exception to this omission, but if the problem is surveyed from an unbiased viewpoint we feel certain that our conclusion in this respect will be sustained. The contention will be made that there are a great number of oil fired continuous furnaces operating successfully. Admitting this statement, let us consider how successful such installations may be and especially the class of service where they have been, or are being, used with economy.

For heavy billet and ingot heating, for large shells and gun rings, or in fact, where a large mass of metal in any form is constantly within the working chamber of the furnace any fuel that will afford the required temperature may be employed successfully. But even for heavy coarse work of this character when temperatures above 1800 degrees Fahr. are required, it will be found that gas will give much better results and be more susceptible of accurate control, as well as more efficiently burned than oil. When continuous furnaces are utilized for small parts requiring accurate temperature control the regulation of an oil-fired continuous furnace is a formidable problem and, except in special isolated instances, it will be found that accurate control cannot be maintained even by the most skilled operators. Automatic control devices have not yet been devised for oil firing which will operate continuously and uniformly. With gas and electricity absolute control may be maintained automatically although continuous gas furnaces must be watched with closer attention than electric furnaces.

The subject of continuous furnaces covers a field of such scope that it is impossible to attempt even a brief synopsis of it in this paper. However,

a word of warning should be inserted at this time, for it is our firm belief that continuous furnaces have been used in many cases where they were not justified by the overall economy secured. Continuous furnaces must be selected and adopted for a particular service only after careful study.

We have no brief against oil fuel and we are accordingly not attempting to condemn this wonderful gift of nature that is such a potent factor in our modern life. Nevertheless, it must be conceded that the rapid adoption of fuel oil for furnace work was occasioned by the cheapness of this commodity prior to 1914, coupled with the low first cost of oil furnaces and the auxiliary equipment required.

Another feature should be mentioned before passing from the general discussion of the hardening furnaces. We refer to the use of lead pots. Scale is, of course, prevented and a uniform product is assured; but as against these advantages, the parts treated must be immersed in salt or some other solution to prevent the adhesion of the lead and even such precautions do not eliminate the necessity for cleaning the gears after treatment. The efficiency of lead pots rarely ever equals 5 per cent and almost never exceeds this point in continuous or overall efficiency.

For the particular service under consideration approximately 80 per cent of the carburized material will be ring gears, or about 17,000 pounds. It is impractical if not impossible to utilize a quenching machine for these gears when they are heated in a lead bath, and as they are bound to become more or less distorted, either when being hardened or quenched or as the combined result of both causes, it follows that extra expense must be incurred for straightening after hardening.

With an electric or an oil or gas-heated furnace, properly fired, it is possible to keep the scaling at such a low amount that it will not be detrimental. This is especially true of the electric gas furnaces. With an oil furnace it is probable that sand blasting may be necessary and even with a gas or electric furnace, light sand blasting may be needed to produce perfect work.

While the use of lead pots may be warranted for particular grades of work, we do not believe that they are a necessity for gear plants such as we are considering in view of the advancements which have been made in both the gas and electric furnace design and operation. Neither do we believe that they are economically sound for this particular service.

Either oil bath, or lead pots, oil, gas, or electric heated gas, heated semimuffle type, or electric heated semimuffle type furnaces may be used for drawing. For the low temperatures required, experience has proven conclusively that the electric furnace is the best equipment for this service. The oil bath is highly satisfactory but it is a messy proposition compared with the electric furnace. Gas furnaces for such low temperatures are controlled with difficulty and cannot be advocated for temperatures below 900 degrees Fahr. The lead pot has the disadvantages previously described under hardening furnaces.

We are now in a position to consider the possible combinations of equipment and heating mediums that may be employed and to ascertain the most economical installation for a complete plant under the assumed premises as to the cost of heating, mediums, the material to be treated, and the character of the heat treatment.

For convenience in presentation we have subdivided the possible grouping into cases as follows:

Case I. All oil-fired	Cost
Efficiency for annealing 30 per cent—carburizing 8 per cent, hardening 14 per cent and drawing 4 per cent.	
(a) Annealing (40,000 pounds net or 51,200 pounds gross), two twin chamber units with cooling chambers, hearth 4 feet x 7 feet 6 inches	$ 22,000.00
(b) Carburizing (22,500 pounds net of 67,500 pounds gross) 8-units, hearth 4 feet x 7 feet 6 inches	24,000.00
(c) Hardening (52,500 pounds net) average charge 100 pounds—24 per 22 units, hearth 3 feet x 4 feet day= 3600 pounds per year	28,000.00
(d) Drawing (22,500 pounds net—Average Temp.—950 degrees Fahr.), (7500 pounds net average Temp. 450 degrees Fahr.), 10 lead pots	30,000.00
2 oil bath furnaces	3,000.00
(e) Storage and complete oil system, 90,000-gallon tank, pumps, blowers, steamp piping, oil piping, etc.	72,000.00
Total furnace equipment cost	$179,000.00
Fuel consumption 1,040,000 gallons per year @ 15c	$156,000.00
Labor—on basis 60 pounds metal per man hour= (30,000/60) x 300 days @ 75c per hour =	105,000.00
Fixed charges 15 per cent of $179,000	26,850.00
Total annual operating cost exclusive of carburizing compound, pots, inspection, and fixed charges on buildings and land	$287,850.00
Cost per pound $0.0319	

Case II. Oil-fired annealing and carburizing, electric hardening and drawing. Efficiency oil same as Case I—Efficiency electric hardening 60 per cent, electric drawing 70 per cent.	
(a) Annealing—same as Case I	$ 22,000.00
(b) Carburizing—Same as Case I	24,000.00
(c) Hardening—6 18-inch hearth rotary electric furnaces complete installed	90,000.00
(d) Drawing—4 30-inch diameter cylindrical drawing furnaces, complete	24,000.00
(e) Transformers—wiring and main switchboard equipment for 600 kilowatts	15,000.00
(f) Oil storage and distribution system	38,000.00
Total cost of furnace and equipment	$213,000.00
Oil consumption 643,000 gallons per year @ 15c	$ 96,950.00
Electric current consumption 3,088,000 kilowatt-hours per heat @ 1½c	46,320.00
Labor on basis 65 pounds metal per man hour	97,000.00

Fixed charges 15 per cent $213,000	31,950.00
Total annual operating cost	$272,220.00

Cost per pound $0.0302

Saving over oil 15,630 or 46 per cent on the incurred investment of $34,000. Note that this saving is made without crediting the oil electric installation with the reduction in the power rates occasioned by the increased load factor imposed by the electric furnaces.

Case III. All natural gas fired. Efficiency anneal 45 per cent, carburizing 12 per cent, hardening 21 per cent, drawing 6 per cent.

Equipment (a) to (d) same as Case I	$107,000.00
Piping mains	10,000.00
Total furnace equipment cost	$117,000.00
Fuel 88,500 M cubic feet gas @ 50c	44,250.00
Labor 65 pounds metal per man hour	97,000.00
Fixed charges 15 per cent of $117,000	17,550.00
Total annual operating expense	$158,800.00

Cost per pound $0.0178

Case III (A) Same as Case III but displacing lead pots with continuous gas drawing furnaces.

Total furnace equipment cost with piping	$120,000.00
Fuel cost 82,000 M cubic feet per year @ 50c	41,000.00
Labor 67 pounds metal per man hour	94,000.00
Fixed charges 15 per cent of $120,000	18,000.00
Total annual operating expense	$153,000.00

Cost per pound $0.017

Case IV. Natural gas annealing and carburizing, electric hardening and drawing.

Equipment (a) and (b) same as Case I	$ 46,000.00
Equipment (c) (d) and (e) same as Case II	129,000.00
Piping mains	6,000.00
Total furnace equipment cost	$181,000.00
Gas consumption 55,000 M cubic feet per year @ 50c	27,500.00
Electric current consumption same as Case II	46,320.00
Labor 70 pounds metal per man hour	90,000.00
Fixed charges 15 per cent $181,000	27,150.00
Total annual operating expense	$190,970.00

Cost per pound $0.0213

Case V. All city gas

Efficiency Annealing 40.5 per cent Carburizing, Hardening, Drawing 13.5 per cent

Equipment (a) to (d) same as Case III (A)	$120,000.00
Piping mains	2,000.00
Total cost of furnace equipment	$122,000.00

Gas consumption 169,800 M. cubic feet @ 80c.....$133,200.00
Labor 67 pounds metal per man hour..... 94,000.00
Fixed charges 15 per cent of $122,000..... 18,300.00

Total annual operating expense.....$245,500.00
Cost per pound $0.0272

Case VI. City gas annealing and carburizing, Electric hardening and drawing
Equipment (a) and (b) same as Case III.....$ 46,000.00
Piping mains 7,000.00
Equipment (c) and (e) same as Case II..... 129,000.00

Total cost of furnace equipment.....$182,000.00

Gas consumption 103,000 M. cubic feet per year @ 80c$ 82,400.00
Labor 70 pounds metal per man hour..... 90,000.00
Fixed charges 15 per cent of $182,000..... 27,300.00

Total annual operating expense.....$246,020.00
Cost per pound $0.0274

Case VII. All water gas
Efficiency annealing 39 per cent Carbonizing 10.5 per cent, Drawing 13.5 per cent
Equipment (a) to (d) same as Case III (A).....$120,000.00
Piping mains 4,000.00

Total cost for furnace equipment.....$124,000.00
Water gas plant complete..... 90,000.00

Total investment $214,000.00
Gas consumption 375,000 M. cubic feet per year @ 30c $112,500.00
Labor 67 pounds per man hour..... 9,400.00
Fixed charges 15 per cent of $124,000..... 18,800.00

Total annual operating expense.....$225,300.00
Cost per pound $0.025

Saving over oil Case I, $67,250 annually on an incurred investment of $25,000

Case VIII. Water gas Annealing and carburizing, Electric Hardening and drawing
Equipment (a) and (b) same as Case I.....$ 46,000.00
Equipment (c) (d) and (e) same as Case II..... 129,000.00
Gas piping mains..... 8,000.00

Total cost for furnace equipment.....$183,000.00
Water gas plant..... 55,000.00

Total investment $238,000.00
Gas consumption 237,000.00 M. cubic feet per year @ 30c .....$ 71,100.00

Electric current same as Case II	46,320.00
Labor same as Case VI	90,000.00
Fixed charges 15 per cent $183,000	29,950.00
Total operating expense	$235,370.00

Cost per pound $0.0262

Case IX. All producer gas

Efficiency. Annealing 34.5 per cent, carburizing 9.3 per cent hardening 16 per cent drawing 11.5 per cent

Equipment cost (a) to (d) same as Case III (A)	$120,000.00
Extra for piping mains	6,000.00
Total cost of furnace equipment	$126,000.00
Cold clean producer plant complete	120,000.00
Total Investment	$246,000.00
Gas consumption 746,100 M. cubic feet per year @ 10c	$ 74,610.00
Labor same as Case VII	90,000.00
Fixed charges 15 per cent of $126,000	18,900.00
Annual operating expense	$183,510.00

Cost per pound $0.0204

Saving over cost of oil, $104,340 per year or an incurred investment of $67,000 or 156 per cent return.

Case X. Producer gas annealing and carburizing, electric hardening and drawing

Equipment (a) and (b) same as Case III	$ 46,000.00
Piping mains	10,000.00
Equipment (c) (d) and (e) same as Case II	129,000.00
Total cost of furnace equipment	$185,000.00
Producer plant	70,000.00
Total investment	$255,000.00
Gas consumption 462,000 M. cubic feet per year @ 10c	$ 46,200.00
Electric current same as Cases II and VIII	46,320.00
Labor same as Cases VI and VIII	90,000.00
Fixed charges 15 per cent of $185,000	27,750.00
Total annual expense	$200,270.00

Cost per pound $0.0236

Case XI. Coal annealing and carburizing, electric annealing and drawing

Efficiency annealing 30 per cent, carburizing 6 per cent, hardening 60 per cent, drawing 70 per cent

(a) Annealing

2-twin chamber units with cooling chambers	$ 27,000.00

(b)	Carburizing	
	4-twin chamber units	38,000.00
(c)	(d) and (e) same as Case II	129,000.00
	Total cost of furnace equipment	$194,000.00
	Coal consumption 4300 tons per year @ $6.00	$ 25,800.00
	Firemen labor 3 men per shift, 3 shifts, 9 men @ 70c or $2.10 per hr x 7200=	15,100.00
	Electric current same as Case X	46,320.00
	Labor 70 pounds metal per man hour	90,000.00
	Fixed charges 15 per cent of $194,000	29,100.00
	Total annual expense	$206,520.00
	Cost per pound $0.023	

Saving over oil $171,530 per year on an investment of $15,000.

Case XII. All electric

Efficiency. Annealing 75 per cent, carburizing 40 per cent, hardening 60 per cent, drawing 70 per cent

(a)	Annealing units	$ 33,000.00
(b)	Carburizing units	60,000.00
(c)	Hardening units	90,000.00
(e)	Drawing units	24,000.00
(f)	Transformers, wiring and switchboard	50,000.00
	Total cost of furnace equipment	$257,000.00
	Electric power cost 9,000,000 kilowatt hours per year @ 1½c	$135,000.00
	Labor 75 pounds metal per man hour	84,000.00
	Fixed charges 15 per cent of $257,000	38,550.00
	Total annual expense	$257,550.00
	Cost per pound $0.0286	

From Table II, Column 10, we can determine at a glance which system is the best to select from the viewpoint of overall economy under the premises which have been used in this paper for the cost of the respective heating mediums. As these costs are somewhat higher than the prevailing rates in most sections of the country at this time and as the relative values may be considered generally comparable for different sections of the country, Table II may be considered as typically representing the merits of the several systems.

Natural gas cannot be secured, and where it is available, the supply is rapidly diminishing and the cost advancing. As this fuel is localized it should be eliminated from our general discussion.

Eliminating natural gas places Case IX, all producer gas, as the best substitute for oil, with Case XI covering coal carburizing and annealing with electric hardening and drawing of almost equal merit with a much reduced initial investment. The great argument in favor of producer gas is that it can usually be applied to existing equipment and this equipment may be gradually replaced by more efficient furnaces from time to time as the occasion warrants.

It will be found in many cases that electric power for heating service is much cheaper than the 1½ cents per kilowatt-hour which we have used. Generally a price of somewhat under a cent per kilowatt-hour can be obtained. With a price of one cent, the all electric equipment, Case XII, shows an investment value of 29.4 per cent. In a number of instances power can be obtained for ½ cent per killowatt-hour and then Case XII shows an investment value of 65 per cent.

It is obvious that each plant must be analyzed taking into account all of the local conditions, but on general principles the following summary generally illustrates the demerits and merits of the several classes of heating mediums when used in furnaces of proper design.

OIL—ADVANTAGES

1. Low first cost for installation
2. Convenient fuel to handle
3. Simplicity of installation

DISADVANTAGES

1. High cost of fuel

TABLE II

Comparative Annual Production, Costs for 30,000 Pounds per 24 Hours

Case	Equipment	Installation cost	Annual operating expenses				Cost per pound metal cents	As compared with Case I	
			Fixed charges	Heat	Labor	Total		Annual saving	% on Investment
1	2	3	4	5	6	7	8	9	10
I	Oil	$179,000	$26,850	$156,000	$105,000	$287,850	3.19	....	....
II	Oil and electric	213,000	31,950	143,270	97,000	272,220	3.02	15,630	7.35
III	Natural gas	117,000	17,550	44,250	97,000	158,800	1.78	129,050	110.00
III(A)	Natural gas continuous	120,000	18,000	41,000	94,000	153,000	1.70	134,850	113.00
IV	Natural gas and electric	181,000	27,150	73,820	90,000	190,970	2.13	96,880	53.50
V	City gas	122,000	18,300	133,200	94,000	245,500	2.72	42,350	34.60
VI	City gas and electric	182,000	27,300	128,720	90,000	246,020	2.74	41,830	23.00
VII	Water gas	214,000	18,800	112,500	94,000	225,300	2.50	62,550	29.20
VIII	Water gas and electric	237,370	27,950	117,420	90,000	235,370	2.62	52,480	22.20
IX	Producer gas	246,000	18,900	74,610	90,000	183,510	2.04	104,340	42.50
X	Producer gas and electric	255,000	27,750	92,520	90,000	210,270	2.36	77,580	30.40
XI	Coal and electric	194,000	29,100	87,220	90,000	206,320	2.30	81,530	42.00
XII	Electric	257,000	38,550	135,000	84,000	257,550	2.86	30,300	11.80

NOTE: Producer plant fixed charges are included in the cost of gas and are charged as heat in column 5, thus they are omitted from column 4.

2. Uncertainty of fuel supply
3. Difficulty of controlling temperature
4. Damage to product caused by No. 3
5. Inefficient combustion
6. Damage to furnaces from high temperatures when burned efficiently
7. Fire hazard
8. Continuous furnaces not practical except for large masses of metal
9. High labor cost due to Nos. 3, 5, 6, and 8
10. Short life of container boxes as compared with nonoxidizing gas fuel

Natural gas—especially valuable for high temperature work

ADVANTAGES

1. High heat value
2. Small pipe mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperature of combustion
5. Accurate temperature control
6. Uniform quality of product

7. Minimum damage to product
8. Simplicity of installation
9. Low cost of installation
10. Low fuel cost
11. Cleanliness of plant
12. Low fire risk
13. Low cost for upkeep due to Nos. 3 and 4
14. Low labor cost
15. Minimum scale

DISADVANTAGES

1. Unreliability of supply
2. Increasing cost due to No. 1

City gas—Especially adapted for high grade, high temperature work

ADVANTAGES

1. High heat value
2. Small pipe mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperature of combustion
5. Accurate temperature control
6. Uniform quality of product
7. Minimum damage to product
8. Simplicity of installation
9. Low cost of installation
10. Cleanliness of plant
11. Low fire risk
12. Continuous furnaces practical
13. Low maintenance
14. Low labor cost
15. Minimum scale

DISADVANTAGES

1. High fuel cost

Water—gas—Most valuable for high grade, high temperature work

ADVANTAGES

1. High heat value
2. Small piping mains due to No. 1
3. Can be burned efficiently
4. Comparatively low temperatures of combustion
5. Accurate temperature control
6. Uniform quality of product
7. Minimum damage to product
8. Cleanliness of plant
9. Low fire risk
10. Minimum scale
11. Freedom from tar
12. Continuous furnaces may be used
13. Long life of furnaces

DISADVANTAGES

1. Cost of installation
2. Installation more complicated than for oil, natural gas or city gas
3. Handling of fuel
4. Disposal of ash

5. Operating labor
6. Restricted fuel supply
7. Menace to life and health due to odorless gas
8. High cost of gas per b. t. u.
9. Danger of back firing due to rapid flame propagation

Cold, clean producer gas—efficient use limited to about 2000 degrees Fahr. unless recuperative or regenerative furnaces are used

ADVANTAGES

1. Can be burned efficiently
2. Low temperature of combustion
3. Accurate temperature control
4. Uniform quality of product
5. Minimum damage to product
6. Continuous furnaces may be used
7. Long life of furnaces
8. Reliability of fuel supply
9. Stability of fuel cost
10. Minimum scale
11. Comparatively low fuel cost

DISADVANTAGES

1. Cost of installation
2. Handling of coal
3. Disposal of ashes
4. Large pipe mains
5. Operating labor
6. Installation more complicated than oil, natural gas, or city gas

Coal—Can be used efficiently only for long heat service

ADVANTAGES

1. High efficiency
2. Low fuel cost
3. Life of container boxes longer than with oil
4. Total operating cost low
5. Reliability of fuel supply
6. Stability of fuel price

DISADVANTAGES

1. High initial cost
2. Repair of firebox due to high combustion temperature
3. Floor space occupied
4. Coal and ash handling
5. Difficulty in keeping competent firemen

Electricity Limited to temperatures below 2000 degrees Fahr.

ADVANTAGES

1. Absolute temperature control
2. No high combustion temperatures
3. Long life of furnaces
4. Simplicity of installation
5. Elimination of piping mains, pumps, and blowers
6. Simplicity of operation
7. Automatic continuous equipment applicable to any service
8. High efficiency

9. Minimum labor cost
10. Small floor space occupied
11. Flexibility
12. Cleanly plant conditions with consequent high morale
13. Quality of product
14. No damage to product
15. Minimum scale

DISADVANTAGES

1. High first cost

We have been able to only superficially scan one small phase of the all important subject of fuel economy. We are well aware of the lack of technical refinement in the arguments presented and that our conclusions are based upon more or less empirical methods of deduction, but as the results are substantiated by tests, they should prove of some value. We are content if this paper serves to stimulate an active interest in the minds of a few upon the subject of furnace operation and economy, because with our existing methods it is safe to claim that at least one-half the *fuel used* in industrial furnaces is now needlessly wasted.

A NEW METHOD OF CASE HARDENING STEEL

By William J. Merten*

(A Paper Presented Before Pittsburgh Chapter)

Iron and low-carbon steels absorb carbon from socalled carburizers very readily when in contact with these carbonaceous materials at temperatures above the upper critical point. The quantity of carbon absorbed depends upon several factors. One of these is the temperature or degree of heat above the critical point of the steel. In other words, the higher the temperature, the faster and deeper the penetration of the carbon.

The character of the carburizer is also an important factor in the successful conductance of case hardening including the depth of the case. Elementary carbon as such is only of secondary importance. Oxygen and nitrogen compounds which are added or are naturally present in the socalled energizers are necessary to generate nascent gaseous carburizing mixtures of carbon monoxide and cyanogen gas (CO and CN).

The percentage of carbon present in the steel used for case hardening has also a marked influence upon the affinity of the material for more carbon up to saturation; more specifically, a low carbon steel absorbs faster than high carbon steel.

The presence of chromium tungsten, or manganese accelerates the absorption of carbon since they form double carbides with the iron. Nickel and silicon, however, retard the absorption. The fact that they form solid solutions with iron may be the cause for this retardation.

From statements made in the second paragraph it is readily conceivable that, if a properly heated piece of steel be brought into contact with pure nascent gas continuously generated in a separate unit or chamber and preferably under pressure, the conditions for case penetration would approach the ideal. A process of this type is the one presented in this paper, preceded by a survey of the processes now in vogue with their disadvantages and deficiencies.

*Metallurgical engineer, Westinghouse Electric & Mfg. Co., Pittsburgh.

The most general and commonly used method of case hardening is conducted by packing steel parts in a metal box filled with carburizing materials and firing the tightly closed box and contents at a sufficiently high temperature for an adequate length of time to give the desired depth of case. This process is quite simple and assures fair success if properly conducted in accordance with a prescribed procedure, experimentally determined to give certain definite results under definite and specific conditions.

The disadvantages of the above process are as follows: (1) uncertainty of proper reaction within closed box; (2) difficulty in duplication of results as predetermined, because of non-uniformity of carburizers; (3) long time exposure of the steel to a heat not well controllable, producing a questionable structural condition; (4) high cost of operation because of inefficiency of the heating method; (5) cost of boxes due to rapid deterioration of same by oxidation.

The second method to be mentioned is case hardening by immersing the steel article in a cyanide bath heated to about 1580 degrees F. This process is convenient and effective on small articles only and where the depth of the required case is not more than .005 in. to .015 in., or where mere surface hardening is wanted. This is a fast caseforming method and from 10 to 15 minutes gives the desired depth. The outstanding disadvantage of this process is that no uniform case can be produced. The parts deep in the melted bath do not get the same depth of penetration as the parts near the surface. The evolution of the cyanide gases at or near the surface favors the penetration and it is hardly feasible to have pots with a large enough surface area to take care of the case hardening of a plant.

The third method consists of dipping a cherry red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, ferro and ferri cyanides, or sprinkling the powdered salt of these cyanides on the red hot steel surface and putting the steel back into the fire again. The case hardening produced in this way is very superficial. In the fourth method the carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design.

The process to be discussed next, although still in the experimental stage, owing to radical changes in the principle employed, appears to present opportunities for efficiency, preservation of the product, simplicity of operation, uniformity of results, speed of operation, reasonable cost, and wide range of utility. This process may be called a regenerated cyanogen gas case hardening.

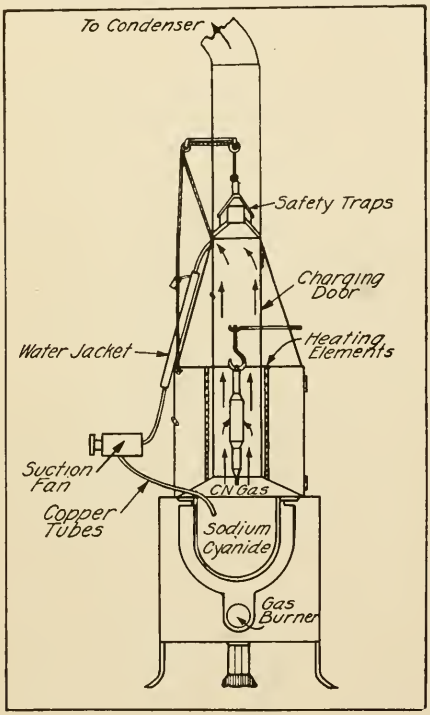
It has long been recognized that the most efficient carburizing gas is cyanogen (CN). The case is of a greater uniformity, is more rapidly produced and penetrates deeper than one produced by carbon monoxide (CO), but the highly poisonous character of the substance has been a serious objection to its use. The tendency is to lead the gas wastefully to the stack and out of harm's way, instead of controlling it to get maximum efficiency.

To case harden steel and iron alloy articles in a stream of cyanogen gas evolved from a container filled with an alkali cyanide salt, heated by electrical energy or other means to accomplish vaporization or boiling of the salt, is the principle upon which this process is based.

The articles or materials to be processed are independently heated

out of contact with the fused cyanide salt. The advantage of this will readily be appreciated on recalling the statements made regarding the fact that case hardening is produced by contact with gaseous and not with solid carbon and more especially with cyanogen gas. The depth of penetration is then only a function of the uniformity of the temperature of the article treated and the duration of treatment. Nascent cyanogen has a speed of penetration of four or five times that of carbon monoxide.

The furnace shown in the accompanying illustration embodies the regenerative principle since the excess gases not absorbed by the steel are forced under pressure into the fused cyanide (CN) bath, are reheated, causing a vigorous stirring of the bath, and a lively evolution of cyanogen gas, leaving with more energy and larger quantities, there-



In this furnace the piece to be case-hardened is suspended vertically between the heating elements where it is heated to the proper temperature. Cyanide salts in the container below are heated by a gas burner which causes them to evolve cyanogen gas. As this gas passes to the top of the furnace a certain amount of it is absorbed by the steel while the balance, by means of the suction fan is returned to the bath. This produces a stirring of the bath and more rapid evolution of the cyanogen gas to surround the steel and cause a deeper penetration. Upon charging or removing the steel, the safety trap opens and the fan stops to prevent the poisonous gas from escaping through the charging door.

fore more vigorously attacking the steel surface, causing accelerated and deeper penetration.

This regenerative type of furnace is a means to use the rather expensive salt economically, as the nitrogen gas on returning will combine with the sodium and a carbon supply in some cheap form such as charcoal can be added to the liquid as required, thereby retaining the original supply of cyanide salt intact.

To prevent the poisonous gases from escaping into the room, the suction fan indicated is shut down before the charging door is opened and a bell ventilating device for inducing draft is arranged so as to open the bell when the fan stops and prior to opening the door.

Parts of the pump or suction fan should be of nonferrous metals such as copper, basic alloys or hard copper. Water cooling jackets or

other protective methods are to be employed for the return flues for hot gases and the nozzle end of the flue must be of hard copper, monel metal or other non-ferrous alloy with a high melting point.

Sodium cyanide melts at 1112 degrees Fahr. and boils at 1472 degrees Fahr. The temperature of the pot must therefore be not less than 1472 degrees Fahr. and to effectively absorb this gas the steel is at a temperature above the critical point or about 1650 degrees Fahr.

The furnace illustrated in the illustration is a design for the processing of shafts, etc., but a slight modification of the upper or steel heating chamber will adapt it to a variety of work. Grates of nichrome metal with knife edge supports are used.

The advantages of this process are the following: (1) temperature control is more perfect since the pyrometer is inserted directly in the heating chamber; (2) a finer, more uniform, and deeper case can be secured than by any other processes and less time is required; (3) the use and storage of carburizers and carburizing boxes is eliminated.

It should be noted that while some of the less important features of this process are still speculative in character, because of the experimental stage of the development, the method is based upon well known principles and the conclusions have been drawn from a careful study of general case hardening practice.

SERIES OF ARTICLES ON CARBONIZING PROCESS

Beginning with the March issue of TRANSACTIONS will be published the first of a series of 10 illustrated articles discussing the case carbonizing process written by Theodore N. Selleck, Chicago, The subject of the first article will be "First Principles of the Carbonizing Process—A Consideration of the Fundamental Facts and Factors of the Process." Titles of the other nine articles will be as follows: "The Relation of Temperature to the Quality of the Case and Core;" "The Relation of Time and Temperature to Depth of Case;" "Comparative Tests of Steel Samples, Carburized and Heat Treated at Different Temperatures;" "Comparative Tests of Steels of Various Types Subjected to Uniform Treatments;" "A Study of Quenching Temperatures and Media;" "Tests for Wearing Qualities of Case Hardened Parts;" "The Application of Gaseous and Liquid Fuels;" "A Study of Methods Employed for Selective Case Hardening;" and "Special Methods Employed in Unusual Applications of the Process."

News of the Chapters

The many chapters of the American Society for Steel Treating have been holding meetings regularly during the winter months, yet it is impossible to give a complete write up of each meeting. Nevertheless, the speakers and the salient points of the meetings are given.

Practically all of the chapters have had membership campaigns on and in spite of the general conditions these have been very successful. Many very interesting letters and announcements relative to increase

in memberships have been received by the national office two of which are reprinted, in this issue.

A Letter

Following is a letter which was sent out by the chairman of the membership committee, Mr. Knerr, of the Philadelphia chapter, to all members of the local chapter:

Dear Sir:

"As a member of the Philadelphia Chapter of the American Society for Steel Treating, you are on the Membership Team. (This is explained in Bulletin No. 1, enclosed.) Will you do *your* part to build up this Chapter,—YOUR Chapter, of the A. S. S. T.?

"The Society as a whole is growing rapidly. There is a Campaign for 25,000 members in the National body, and that goal is likely to be reached soon. The Philadelphia Chapter must meet the pace. More than that, we must get to the head of the procession, where we belong.

"Philadelphia is the greatest industrial center in America. A large proportion of all its numerous and varied industries depend in some measure upon the proper heat treatment of steel. In many of them, heat treated steel, in some finished form, is the principal product. Of the others, there is hardly a modern plant that does not have at least its Tool Shop, where tools, jigs or parts are made, repaired and *heat-treated.* Moreover, we are leaders in the production of high grade steel, pyrometers, metal testing machines, heat treating equipment and materials. The arts and sciences connected with the treatment of steel are taught in our trade schools and engineering colleges.

"Therefore, you see that there are literally thousands of men in and around this city who are concerned with the treatment of steel. For these men the A. S. S. T., and in particular, the Philadelphia Chapter, exists. It needs them. They need it.

"Our Chapter should number 1000 members by January 1, 1921. This is some contract. Can we make it? Whether we can, depends upon *you* and every other live member.

"When you joined the Society you agreed, in your application, to promote the objects of the Society insofar as it should be in your power. Perhaps you have not yet had an opportunity or the inclination to present a paper or to render any other special service; or perhaps you have already served in many ways. In either case, this is a chance to do something worth while, something of direct benefit to the Society, to yourself and to your friends. A bigger and better Chapter means greater value to every member.

"You, no doubt, know personally a number of men whose membership in the Society would be a benefit to themselves and to us. Other such men are near you in your office or plant, or in your daily path, if you will but take the trouble to look them up.

"Make it a point to see each of these men without delay. Tell them about the "Steel Treaters," what the Society is and does, and why *you* are in it. Show them a copy of the TRANSACTIONS. Bring them with you to the next meeting.

"If they are qualified to join, sign them up, indorse the application, and send it in.

"Here are the qualifications for membership:

"'All persons of good character who are in any way interested in the work of the Society are eligible for admission to the same." (The Constitution A. S. S. T., Article V, Section). The initiation fee is temporarily suspended. A deposit of $2.00 places a man on the rolls.

"Yes, we know you are busy, but remember,—"Every man owes some of his time to the upbuilding of the profession to which he belongs."—T. R.

"Will you do *your* part *now?*

H. C. KNERR, Chairman
Membership Committee."

"P. S. Some people out West *think* we are asleep. Can they prove it by YOU?"

Another Letter

"Bill" Abel the active chairman of the membership committee of the Cleveland chapter drafted the following letter which was sent out to 500 firms in the vicinity of Cleveland, and which produced good results:

"Your product being one in which the proper heat treatment of steel is very essential suggests to us the thought that you or some of your representatives would be interested in the American Society for Steel Treating.

"The many advantages to be derived from becoming associated with metallurgists, chemists, managers, superintendents and steel treaters are evident. The opportunity of meeting these men and the exchange of ideas should be very valuable to you.

"A membership in this Society entitles one to attend the meetings, which are held once a month or oftener, at which time an interesting paper is usually read by some notable in his particular line.

"The next meeting will be held at the Hotel Statler in the rooms of the Cleveland Engineering Society, dinner to be served at 6:30 and the meeting at 8:00 p. m. The speaker for the meeting of December 27 will be Mr. W. E. Jominy, Metallurgist for The Packard Motor Car Co. His subject will be: "The Selection and Treatment of Materials for Automobiles".

"In addition to the privilege of attending these meetings, members receive the regular monthly publication which has become recognized as the leading journal devoted to heat treating and allied lines.

"If you desire further information regarding the aims of the Society, kindly drop us a line and we will have a member call on you to explain in full its objects and advantages.

Yours very truly,

W. ABEL."

"P. S. We wish to extend to you a very cordial invitation to attend the next meeting of the Society, which will be held as stated above. Come to the dinner if you can."

ANNUAL VISITS BY THE NATIONAL PRESIDENT

Lieut. Col. White, national president of the American Society for Steel Treating, will visit a number of the Eastern chapters during the mid-semester recess of the University of Michigan.

President White's itinerary calls for the following schedule:

Monday, February 7	Boston
Tuesday, February 8	New Haven
Wednesday, February 9	Bridgeport
Thursday, February 10	Hartford
Friday, February 11	Springfield
Monday, February 14	Providence
Tuesday, February 15	New York
Wednesday, February 16	Philadelphia
Thursday, February 17	Baltimore
Friday, February 18	Washington

MILWAUKEE CHAPTER

H. J. Stagg, assistant general manager of the Halcomb Steel Company delivered an address before the Milwaukee chapter on Dec. 15, at the Hotel Medford. The meeting was preceded by a dinner which was quite largely attended and the meeting proved very interesting. The discussion was lively.

ST. LOUIS CHAPTER

Prof. J. H. Keller, professor of mechanical engineering at the Lewis Institute, Chicago, addressed the members at the December meeting at the Planters' Hotel, on Monday evening, Dec. 13. The attendance was quite large and all thoroughly enjoyed Prof. Keller's address on "Steel, Its Selection and Treatment." The discussion was voluminous and the meeting enjoyable.

BALTIMORE CHAPTER

The November meeting was addressed by Marshal Medwedeff, formerly of the Sampson Tractor Co., Danville, Wis. Mr. Medwedeff selected as his subject, "High Speed Steel," which proved to be very interesting and instructive. The discussion following the address brought

out many important points with reference to the treatment of high speed steel.

The December meeting was addressed by G. S. Hamlin, Jr., of the Atlas Crucible Steel Co., Dunkirk, N. Y., who spoke on "The Manufacture and Uses of Alloy Steels," illustrating his talk with moving pictures. The meeting was held in the assembly room of the Consolidated Gas Electric Light & Power Co.'s building and a large audience was well attended. Everyone thoroughly enjoyed the talk by Mr. Hamlin.

BOSTON CHAPTER

S. C. Spalding, metallurgist of the Halcomb Steel Co., Syracuse, N. Y., delivered a very interesting paper before the chapter in the Engineers' Club, on Dec. 20. The discussion was of a very practical nature and full of valuable experiences. At the close of the meeting an excellent buffet lunch was served to 80 members in attendance.

On Jan. 7, Maj. A. E. Bellis of the U. S. Arsenal, Springfield, presented an interesting and enjoyable paper on "Some of the Essentials in Treating High Speed Steel." The discussion was very general and keen, and the meeting proved very enjoyable and profitable. Over 100 were in attendance.

PROVIDENCE CHAPTER

The regular monthly meeting for November was held on Wednesday evening, Nov. 24 at the Providence Engineering Society rooms. The speaker was E. F. Collins, consulting engineer of the General Electric Co., who read a paper on "Relative Thermal Economy of Electric and Fuel Fired Furnaces." The paper was illustrated with lantern slides. Mr. Collins is a leader in the electrical furnace field, and he presented a paper which amply repaid all those members who attended. The discussion was quite interesting and many important questions were propounded to the speaker and successfully answered.

The December meeting was held on the 29th at the Providence Engineering Society rooms when A. H. D'Arcambal, consulting metallurgist of Pratt & Whitney Co., gave a very interesting paper on "Hardening of High Speed Steel." The discussion following the presentation of Mr. D'Arcambal's paper was such as to show that the selection of the subject was very appropriate and that the members decidedly were interested in the subject.

HARTFORD CHAPTER

The December meeting of the chapter was attended by 100 members of the Society. The meeting was held in the Chamber of Commerce auditorium on the 9th. The speaker of the evening was Charles Green, chief chemist of the Henry Souther Engineering Co., who presented a paper on "Fundamental Chemistry." George Jayne, of the Peter A. Frasse Co., spoke on the subject of "Manganese."

There was a good discussion on the papers and an interesting phase of the meeting was the opening of the question box where there had been deposited a number of questions relative to the problems confronting the members of the Society. These questions were answered to the satisfaction of the members present. At the close of the meeting refreshments were served.

PHILADELPHIA CHAPTER

The November meeting was held in the auditorium of the Engineers' Club, and was attended by about 100 members and guests. A paper was

presented by Dr. W. M. Mitchell, metallurgist, who selected as his subject, "Troubles|" Dr. Mitchell illustrated his talk. At the close of the presentation of the paper, an excellent discussion was entered into with a great deal of freedom by the members and guests.

The results of the extensive campaign carried on by the Philadelphia chapter have begun to make themselves shown in the increased attendance and the interest of the members.

The January meeting was held at the Engineers' Club, on Saturday evening, January 8, when G. W. Tall, of the Leeds & Northrup Co., presented an illustrated paper on the "Hump Method of Heat Treatment." Mr. Tall had a furnace in operation during the talk and gave practical demonstrations of the work.

CHICAGO CHAPTER

As results of opening up of educational courses at the Armour Institute and at the Lewis Institute, under the auspices of the local chapter, three classes have been organized and are full to capacity. Two of the classes are located at the Armour Institute, and one at the Lewis Institute.

A great amount of credit is due to T. E. Barker the chairman of the educational committee and to the various members of his committee and also to the Chicago chapter who have devoted largely of their time and efforts in the preparation of the text for the courses.

The December meeting was held at the Lumbermen's Association, fourth floor at 11 S. LaSalle St. A dinner was served at 6:30 to 125. The speaker of the evening was H. J. Stagg, chairman of the Syracuse chapter and a member of the Board of Directors of the National Society. Mr. Stagg presented a very interesting paper, illustrated, which was received heartily by the large number in attendance. The discussion following was quite open and free. Following is an extract of a report from the secretary of the Chicago chapter with reference to the above meeting:

"We all knew that Stagg had something good, but even at that he surprised us. You know how hard it is for a speaker who is giving even only a little theory with his paper to hold his audience. Well, last night the men "ate" all that Howard J. was feeding, and when, for the nth time he remarked, 'heat slowly, thoroughly, and evenly, etc.,' one could be sure that the above at least had "gone home" with everyone present."

PITTSBURGH CHAPTER

C. M. Brown, vice president of the Colonial Steel Co., presented a paper on "Standard Specifications of Tool Steels" before the Pittsburgh chapter at its December meeting at the Chatham Hotel. This subject, since it is becoming more and more important daily, is one which the manufacturer and consumer have to wrestle with, brought out a good attendance as the members were very anxious of getting the facts from one who is thoroughly familiar with tool steels. The National Secretary was supposed to have been present at this meeting but was prevented from doing so by illness.

SYRACUSE CHAPTER

The second regular meeting of the Syracuse chapter was held on Nov. 23 in the rooms of the Technology Club in the Vinney Building. The speaker of the evening was Frank Lounsberry, metallurgist of the Atlas Crucible Steel Co.

The "baby" chapter came through with an attendance that far surpassed even the most optimistic expectations. It had arranged for the use of the auditorium of the Technology Club, which room will seat about 150. Before 8 o'clock the room was filled and then overflowed into a connecting room. There were 250 in attendance by the time all arrived. The speaker was very enthusiastic in his remarks about the spirit of the meeting. The applications for members in the chapter number 120. As soon as business conditions revive the Syracuse chapter will have no difficulty in hitting the "bull's-eye" at 250.

The third meeting of the chapter was held in the same rooms on Tuesday, Dec. 21, with J. V. Emmons, metallurgist of the Cleveland Twist Drill Co., as the speaker. Mr. Emmons presented a paper on "Tool Hardening Problems," illustrated. When the invitations were sent out, the members were requested to bring their problems with them. This, they did, and consequently a very lively and enjoyable meeting was held. A dinner was served in the dining room adjoining the auditorium.

BUFFALO CHAPTER

John Miller, well known metallurgist of the Pierce Arrow Motor Car Co., presented a paper on "Fatigue Breakdown of Metal." Inasmuch as probably no other man in or about Buffalo has as many varied steels to work on as Mr. Miller, his paper proved to be very enjoyable and instructive. The meeting was held on Monday, Dec. 6 at the University Club.

The January meeting was held on the 4th of the month at the University Club when a paper was presented by Mr. H. J. Stagg. The attendance was very satisfactory and the meeting was preceded by a dinner. An extensive discussion followed Mr. Stagg's paper and many of those present gathered a new idea as to the important function served by the local chapter in the community.

BRIDGEPORT CHAPTER

The December meeting of the Bridgeport chapter was held in the parlor of the Stratfield Hotel, on Dec. 16. C. W. Copeland, metallurgist of Hare's Motors, Inc., presented an interesting illustrated lecture on "Metallography and Microstructure of Steel." This was the first of a series of lectures on this branch of steel treating, and a large number were in attendance as they desired to secure a thorough understanding of this important subject.

SPRINGFIELD CHAPTER

The November meeting was held on the 29th of the month in the Chamber of Commerce hall, and was addressed by W. J. Kaup, consulting engineer, New York, who selected as his subject, "Steel and the Man." Mr. Kaup has an international reputation, and the large attendance of the members felt well repaid for having been in attendance because Mr. Kaup's paper was interesting and instructive, and the discussion following it very enlightening.

W. R. Shimer, sales metallurgist of the Bethlehem Steel Co., presented an illustrated talk on "Manufacture of Steel," before the Springfield chapter on Friday evening, Dec. 17. The session was held in the Technical High School Hall in order that they might have the facilities for moving pictures. Mr. Shimer commenced with the ore, and continued through the blast furnace to the converter into the open hearth

furnace and also the crucible, ending with a detailed talk on manufacturing tool steels. Mr. Shimer has a very pleasing personality and it was a pleasure to all of the large number in attendance to have had the opportunity of listening to him and enjoying the paper.

The January meeting of the Springfield chapter was held in the auditorium of the Springfield Gas Light Co.'s building. James Cran, demonstrator for the Ludlum Steel Co., Watervliet, N. Y., gave practical demonstrations of the "Forging and Heat Treatment of Carbon and High Speed Steels." This was followed by an exhibition of artistic forging. The meeting was without doubt one of the most interesting which the Springfield chapter has had. Practically all of the members were in attendance.

CINCINNATI CHAPTER

The December meeting of the Cincinnati chapter was held on Friday evening, Dec. 10, in Hall D, Odd Fellows' Temple. The following program was run off on schedule time.

7:30 p. m.—Important business transacted.

8:00 p. m.—"EFFECT OF THE ELEMENT CARBON ON STEEL" by W. L. Fleming, metallurgist of the Andrews Steel Co.

8:15 p. m.—Discussion on the above subject.

8:30 p. m.—"FURNACES AND FUEL"—with special emphasis on conversion from gas to oil—By Dr. J. C. Hartzell.

9:30 p. m.—Comments on the last issue of the Transactions, the publication of the American Society for Steel Treating, and an open discussion on same.

The meeting was very well attended and proved very profitable.

DETROIT CHAPTER

The meeting on Dec. 20 was held in the Board of Commerce rooms at which a round table meeting took place, on the interesting subject of "Carbonizing." Following are the speakers, and each one prepared a ten minute paper on the subject:

A. T. Haggerty—Central Gear Co.
John Secholtz—General Motors Co.
Herbert M. Bray—Lincoln Motors Co.
H. G. Kiefer—Studebaker Corp.
L. A. Danse—Cadillac Motor Car Co.
J. M. Watson—Hupmobile Motor Co.

A discussion followed the presentation of each paper. This round table idea has proven itself to be of real value in having presented the ideas of the members on some subject. The way those in attendance entered into the discussion and asked questions proved conclusively that more meetings of this particular nature would be especially desirable.

The November meeting proved to be one of exceptional interest. It was addressed by J. A. Brown, vice president of the W. S. Rockwell Co., New York. Mr. Brown selected as his subject, "Factors Governing the Production of Heated Products." Mr. Brown thoroughly understands the subject on which he talked, and consequently was able to answer the many questions propounded to him. Over 100 were in attendance.

TRI-CITY CHAPTER

Harold Brown, the active, wide-awake secretary of Tri-City chapter, ends his announcement of the meeting for Dec. 16 with this sentence:

"We expect to see your smiling face Thursday evening." That together with the fact that all the members with machines are hauling to and from the meetings those who do not have them, assisted in bringing out a large attendance. The speaker of the evening was Dr. French, chief chemist of the Dearborn Chemical Co., who presented a real message regarding "Quenching Mediums," and the greatest enemy of the metallurgical world, "Rust." The meeting in point of interest was one of the best which the local chapter has held.

SCHENECTADY CHAPTER

The opening meeting of the Schenectady chapter was held on Dec. 7 in the metallurgical laboratory of the American Locomotive Works. Prof. McKibben, instructor in civil engineering at Union College gave a talk on "Tests on Full Size Steel Plate Girders." E. J. Edwards, engineer of tests at the American Locomotive Works also gave a short talk. A short business session was held after which light refreshments were served. It was the privilege of all present to have access to all parts of the new metallurgical laboratory of the American Locomotive Works. First hand information was gained as to how heat treating problems are solved. Men were present to explain details of operation of apparatus or machinery in which the various members were interested.

The January meeting was held at the same place on the 7th of the month, when G. R. Brophy, research metallurgist of the General Electric Co., presented a talk on "True Action of Cyanide in Case Hardening," and spoke also on "Nitrogen Content in Carbonized Cases." Considerable time was devoted to discussion, and interesting questions were brought out.

CLEVELAND CHAPTER

The December meeting of the Cleveland chapter was held in the rooms of the Cleveland Engineering Society, on the 27th. Dinner was served at 6.30. The speaker of the evening was W. E. Jominy, metallurgist of Packard Motor Car Co., who selected as his subject, "The Selection and Treatment of Materials for Automobiles." The paper was of such a nature that it was unusually interesting to everybody present. All of the officers and the Board of Directors of the National Society were present at this meeting, inasmuch as they had held a conference in Cleveland on that day.

INDIANAPOLIS CHAPTER

The December meeting of the Indianapolis chapter was addressed by Mr. J. V. Emmons, metallurgist of Cleveland Twist Drill Co. Mr. Emmons, because of his broad experience in this particular branch of heat treating, handled his subject, "Tool Hardening Problems," in a very thorough and capable manner. E. Haynes, of Kokomo, who is one of the original members of the Society, and who is at present serving on the United States grand jury in Indianapolis, was presiding officer at the meeting. The discussion was of a very interesting nature, and the meeting proved to be a decided pleasure to all those in attendance.

The January meeting was held in the Chamber of Commerce rooms on th 10th of the month when H. E. Hayward, metallurgist of the Link Belt Co., presented an illustrated lecture on "Malleable Iron." Mr. Hayward handled his subject in a very intelligent manner and brought out many points of decided interest to those present.

TOLEDO CHAPTER

The December meeting was held in the rooms of the Chamber of Commerce on the 9th of the month, when a paper was presented by S. C. Spalding of the Halcomb Steel Co., Syracuse, N. Y. The meeting was preceded by a supper, and was attended by about 50 members and guests.

NEW YORK CHAPTER

On Nov. 17, W. R. Moore, sales engineer of the Norton Co., Worcester, Mass., presented a very interesting paper on "Grinding." Inasmuch as practically 90 per cent of the difficulties with heat treated products encountered is due to faulty grinding, this subject proved to be very interesting and gave the heat treaters an opportunity to lay some of their difficulties at the proper source. A very interesting discussion followed the presentation of Mr. Moore's paper.

The December meeting was held at the Machinery Club on the 15th, when H .P. MacDonald, of Snead & Co., Jersey City, presented a paper on "Electrical Heat Treating of Steel." Over 100 were present at the meeting and all contributed to making it a very lively one.

NORTHWEST CHAPTER

The December meeting of the North West chapter was held in the Manufacturers' Club rooms in the Builders' Exchange Building, at Minneapolis. Over 100 members and guests gathered to greet H. J. Stagg, a member of the National Board of Directors. Mr. Stagg presented a very interesting paper that met with the hearty approval of the large number present.

On Jan. 17, Mr. Richardson, of Midvale Steel & Ordnance Co., presented a six reel moving picture on the "Manufacture of Iron and High Speed Steel." Mr. Richardson's talk accompanying the slides was very interesting and at the close of the meeting a lively discussion was participated in by many present, while all joined in enjoying the buffet lunch which was served by the chapter.

A. F. McFarland, of the Vanadium Steel Alloy Co., presented a paper at the monthly dinner of the chapter on Tuesday, Nov. 30. Mr. McFarland selected as his subject, "Some Notes on Heat Treatment and Structure Characteristics of High Speed Steel." Mr. McFarland's paper was illustrated by lantern slides. Over 100 took the opportunity to profit by his highly interesting and educational paper.

THE ADVANCEMENT OF HEAT TREATING STEEL

(Portions of a Communication to President A. E. White)

The members of the American Society for Steel Treating may rest assured of the appreciation afforded a pioneer of heat treating in observing the remarkable advancement in the science of heat treatment of steel since the writer 31 years ago suggested and made the first tentative efforts, of annealing and systematically heat treating steel car axles. Prominent metallurgists ridiculed his use of the microscope. The revelations of the refinement of processes of how to treat steel scientifically shown at the recent convention and exhibition by the Society at Philadelphia, indicated

AMERICAN SOCIETY FOR STEEL TREATING.

Hartford Chapter

PROGRAMME
1920 - 1921

	PRACTICAL DEVELOPMENT OF STEEL FROM ORE TO TREATER	DISCUSSION OF ELEMENTS AND TREATMENT	BALANCE OF TIME
Nov. 11,	Ore - Coke	Phosphorous & Sulphur	
Dec. 9,	Fundamental Chemistry	Manganese & Spiegle	Are's and "Aint's"
Jan. 13,	Blast Furnace	Carbon & Silicon	Terminology
Feb. 10,	Wrought Iron	Nickel	
Mar. 10,	Bessemer	Chromium	Special Papers
Apr. 14,	Open Hearth	Vanadium	To be announced
May. 12,	Crucible & Electric	Tungsten	
June 9,	Fabrication	Molybdenum, Titanium, Cobalt	

"DON'T BE A SPONGE, BUT IF YOU MUST,
ONCE IN A WHILE GIVE YOURSELF A SQUEEZE."

D.H. STACKS Chairman — M.E. GERE Vice Chairman — C.T. HEWITT Sec. & Tres.

COMMITTEES

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decidedly that the world and the American engineer move, and move rapidly, when occasion requires.

It was a pleasure to study that exhibit with its refinements and then hark back to the strenuous times of 35 and 40 years ago when it was difficult to convince the steelmaker and forger that good steel could be spoiled by improper heat treatment and bad steel could be improved by judicious heat treatment, and that the boilermaker's mistreatment of steel plate, by persistent treating and flanging steel like wrought iron plate, caused the steelmaker to produce a metal so honeycombed that it soon failed in service. The reason for the latter was that honeycombed steel plate more constantly displayed the flanging qualities required by the boiler maker. That was the reason Barba of France, when first using steel for the French navy, put carpenters in the smith shop to heat and flange the steel because they, knowing nothing about working metal, were willing to follow Barba's direction of steel treatment.

There is one vital feature, however, to be observed when treating steel of any kind and composition, and one which holds as good today as it held good 40 years ago, and that is the observance of a judicious and careful rate of heating and cooling of the steel. An ideally uniform and homogeneous steel coming from the melting pot or the furnace is not known and if it were known, rapid heating or cooling would change that uniformity. Hence, a cardinal principle of steel treatment is slow heating and cooling, except for hardening, because of the different melting points of the elements composing the steel. Since the various elements in the steel travel at a given degree at a given heat, trying to establish an equilibrium according to their chemical affinity, if insufficient time is given for the various elements to dissolve and to diffuse gradually through the mass, the result will be as heterogeneous a metal as it was before heating, possibly more so. It is remarkable how even inferior steel can be improved and made serviceable by slow heating, which allows sufficient time for the diffusion of elements.

When steelmaking and using was in its infancy for structural purposes, an endless variety of difficulties arose due to lack of experience. Segregation was particularly troublesome and it was remarkable that slow heating and consequent chance for diffusion of elements reacted to make segregated steel serviceable where the forces of destruction were not too varied and complex. To the young engineer, who is eager for quantity production, this property of steel demanding time and patience for the diffusion and equalization of elements to attain and equilibrium of forces, is often trying if not harassing, but it is a natural law, the nonobservance of which confirms the old saying that haste makes waste.

Paul Kreuzpointner,
1400 Third Avenue,
Altoona, Pa.

Commercial Items of Interest

John L. Cummings, until recently connected with the S. Obermayer Co., is now secretary of the Mac Co., Inc., 293 Thirty-fourth avenue, Milwaukee,

a new company which he organized. The company will manufacture refractories and foundry materials. Mr. Cummings was in charge of the S. Obermayer Co. exhibit at the recent Philadelphia convention of the society.

John C. Pangborn, vice president of the Pangborn Corp., Hagerstown, Md., manufacturer of sand-blasting and allied equipment sailed from New York Nov. 27 on THE OLYMPIC for Southampton, Eng. He will spend several months in Europe on business.

W. S. Rockwell Co., 50 Church street, New York, has issued an 8-page bulletin, on heat treatment furnaces of the car and car and ball type. This pamphlet, which is illustrated, points out the applicability of car type and car and ball type furnaces to the heat treatment of material that can not be handled advantageously in other types of furnaces. The discussion includes factors governing selection of the type best suited to individual manufacturing requirements; influence of unequal cooling on the quality of the finished product; and typical heat treatment installations involving the use of car and car and ball type furnaces.

H. R. Harris, manager of the metals division of the Quigley Furnace Specialties Co., New York, has purchased from the Quigley company this department including all rights related to the products and will handle this business on a more extensive scale under the name of the General Alloys Co. Headquarters will be maintained at 122 S. Michigan avenue, Chicago, and 26 Cortland street, New York, while branch offices will be established in principal cities. A local sales office will be located in the Chemical building, 117 North Dearborn street, Chicago. Mr. Harris founded the metals division of the Quigley company and has been its manager from the start. Mr. Harris has had wide experience with heat resisting materials and is considered an authority on the subject. He is the author of numerous articles on heat treating containers, high temperature resisting alloys, etc., and has designed heat treating equipment for many of the largest plants in the country.

Mr. Harris was formerly associated with the Diamond Power Specialty Co., and the Calorizing Corp. of America in executive capacities, and prior to his connection with the Quigley company, was general manager of the Swedish Crucible Steel Co. The General Alloys Co. will continue with the offices formerly occupied by the metals division of the Quigley Furnace Specialties Co., New York, Detroit and other cities and is retaining a large part of the former organization including P. F. McGovern, A. L. Grinnell and H. P. Rounds and others. Mr. Harris plans to increase this organization soon.

J. P. Greenwood, mechanical engineer, is now associated with the Smith Gas Engineering Co., Dayton, O., as southwestern representative. Through his former position as Texas representative of the N. A. S. E. and years of contact with southwestern plant. Mr. Greenwood has formed a wide circle of friends and little introduction is needed to power users in southwestern states. Mr. Greenwood will introduce the gas producer in one of its most promising fields. Southwestern fuel, particularly lignite, is considered satisfactory for use in gas producers, and Mr. Greenwood will endeavor to show economies made possible through the use of lignite in generating gas power, either as engine or industrial fuel. His headquarters will be 219 Cotton Exchange building, Dallas, Tex.

Concluded on Page 43, Advertising Section

TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, March, 1921 No. 6

WATCHING THE WATCH DOG

Of all the auxiliary equipment utilized in heat treating operations, the pyrometer perhaps is the most important. Whether manual or automatic, this piece of apparatus serves as the watch dog of furnace temperatures, certain cycles of treatment being governed almost entirely by its readings. All conditions being equal, uniform results in product are obtained time and time again through the faithful service of these instruments.

Regardless of the type and operating principle, these devices are necessarily delicate and may become inaccurate in spite of the most careful handling and manipulation, their falsity sometimes being so slight as to remain undetected until the product fails in test. Much trouble from this source can be minimized by periodic checking of pyrometers with instruments either standard or known to be correct. For the smaller plants such a policy may have disadvantages, however, it is reasonable insurance against lowering the standard of product.

Realizing the importance of pyrometer equipment, some manufacturers of this equipment have instituted a service whereby traveling representatives of the company inspect and check the apparatus at given intervals. Larger plants which use a number of pyrometers frequently prefer to check their own instruments, and for this purpose, the department of metallurgy, United States bureau of standards, Washington, carries in stock pure specimens of various metals having known thermal properties. These metals are made and sold expressly for the purpose of checking pyrometers when time does not permit sending the instruments to the bureau. Either of the two methods produces desired results.

COMBATTING INDUSTRIAL WASTE

Undertaking of a survey on industrial waste and the proper methods in its elimination were announced at the recent meeting of the Engineering Council of the Federated American Engineering Societies in Syracuse, N. Y. Although still a young organization, the society feels the need of all engineers joining hands in purging industry of extravagant habits and methods which gained a foothold when during the war production was demanded at any price. The day for those methods is passed for the present business depression is effecting its own house cleaning—the present demand of industry is economy.

The Federated American Engineering Societies has chosen a huge problem as its first achievement and one in which it has the support, not only of manufacturers but of the public. Conditions are ripe for attacking waste in a whole-hearted and determined way. As evidencing the

FIG. 1—MANUFACTURERS BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE 1921 CONVENTION WILL BE HELD SEPT. 19-24. FIG. 2—INTERIOR OF SAME BUILDING SHOWING 25,000 OF THE 78,000 SQUARE FEET OF EXHIBITION SPACE. FIG. 3—WOMAN'S BUILDING WHERE SESSIONS WILL BE HELD. IT IS 400 FEET FROM EXHIBITION HALL

sincerity with which the movement has been started, the organization already has a committee making a national survey of conditions and upon its report and recommendations to the Council will depend the procedure to be followed in the assay. In the interest of industry and the nation's welfare, most hearty indorsement is given to the new movement.

NOMINATING COMMITTEE TO MEET

The Nominating Committee of the Society will hold a meeting in the executive offices in Cleveland on Friday, March 25, to nominate officers to fill the vacancies for the year 1921-1922.

The offices for which nominations are to be made are as follows:

President.

One Vice President.

Treasurer.

One Member of Board of Directors.

Members of the Society are requested and urged to send recommendations to the chairman of this committee, J. Fletcher Harper, Allis Chalmers Co., Milwaukee, Wis.

The other members of the nominating committee are: H. G. Kiefer, Studebaker Corp., Detroit; A. E. Bellis, Springfield Armory, Springfield, Mass.; A. W. F. Green, John Illingsworth Steel Co., Philadelphia, and C. U. Scott, C. U. Scott & Son, Rock Island, Ill.

INDIANAPOLIS WINS 1921 CONVENTION AND EXHIBITION

The Board of Directors has decided to hold the third annual convention and exhibition of the American Society for Steel Treating during the week of Sept. 19 to 24 inclusive, at Indianapolis.

Before arriving at this decision the Board gave serious consideration to the many invitations received. Because of the enormous size to which the exhibition has grown, there are very few cities having a sufficiently large building capable of accommodating the exhibition.

Indianapolis was fortunate in having on the State Fair Grounds, the Manufacturers' Building, 360 feet in length by 220 feet in width, the total floor area of which is 78,000 square feet. The central section of this building measuring 240 feet x 100 feet, is known as the "Sunken Garden", and is 20 inches below the level of the surrounding floor space. The building is new, well lighted, and excellently adapted for exhibition purposes. The management has divided the floor space into 161 10 x 20-foot sections. The booths along the north wall are to be used for the live exhibits and are supplied with gas and compressed air, while arrangements also have been made for the exhibitors requiring heavy electrical current to locate on the promenade on the same side of the building. The floor plan probably will be ready for distribution by March 15, when reservations can be made.

The meetings are to be held in the Women's Building, located about 400 feet from the exhibition hall, where there will be available three or more large meeting rooms where it will be possible for several sectional meetings to be held simultaneously.

The Indianapolis chapter of the Society is engaged actively in making comprehensive plans for successfully carrying on its part in making the entertainment of the visiting members and guests a notable occasion. George Desautels, national member of the Program and Papers Commit-

tee, is organizing the members of the chapters into 15 committees, not the least of which is the one devoted to the entertainment of delegates and their wives. The Indianapolis chapter plans to raise $5000 for entertainment purposes, and expects to show the visitors a very enjoyable time.

The requests that have been coming into the National office at 4600 Prospect avenue, Cleveland, for information as to reservations and floor plans, indicate that the exhibition this year will be larger than it was at Philadelphia last year, and all indications point to an attendance of at least 15,000 people.

A DISCUSSION OF MOLYBDENUM STEELS

By Charles McKnight*

(A Paper Presented Before the Pittsburgh Chapter)

Molybdenum steels were first brought into use in answer to the exacting demands of the war. They served their purpose admirably but in the reaction which followed the war they fell into disfavor, perhaps because the steel users "fear the steelmakers even bearing gifts", perhaps because one or two bad heats of molybdenum steel were allowed to get out and fell down in service. Whatever the reason, a counter-reaction now is going on and these steels are receiving an almost enthusiastic reception, especially from automobile manufacturers.

The first use of molybdenum in alloy steels was probably in high speed tool steel either to replace or to augment the effect of tungsten. In this connection, a report on the efficiency of tool steels presented before the British Iron and Steel institute in 1919 by Messrs. Arnold and Ibbotson shows that a chrome-molybdenum-vanadium steel containing 5.79 per cent molybdenum removed more metal in a machining test than did a chrome-tungsten-vanadium steel containing 15.93 per cent tungsten and otherwise practically identical with the first steel. It would appear from this that one part of molybdenum produced substantially the same results as 2.7 parts of tungsten.

These experiments, however, had little to do with the development of the socalled commercial molybdenum steels, referring to steels containing less than one per cent of molybdenum which can compete on a cost basis with other structural alloy steels. It appears that the first extensive experimentation along these lines with a broad enough scope to be of really great value was undertaken by Messrs. Wills and Chandler at the Ford Motor Co. factory. At this time the Ford car was built for the most part of steel which was ordered to conform to the analysis: Carbon, 0.23-0.28 per cent; chromium, 1.00 per cent; vanadium, 0.18 per cent; and manganese, 0.70-0.90 per cent.

This analysis was so written that the steelmaker would average 7 per cent of his heats on the low side and 15 per cent on the high side as far as carbon is concerned. The low carbon heats were used for case hardened parts and the high carbon ones for the oil quenching parts. Thus this one specification covers all parts of the car except specialties, such as balls for ball-bearings and magnet steel for the magneto.

On account of the monopoly on vanadium and the royalty on its use a search was made for a steel which would replace the chrome-vanadium for universal use in an automobile—that is, for one which, coming low in

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*President, the Carbon Steel Co., Pittsburgh.

carbons, could be used for case hardening, coming high could be used for oil quenching, and within the range would be suitable for the structural parts of the car. There is no such steel available. For example, to replace chrome-vanadium with a straight chrome steel of the same physical properties it would be necessary to raise the carbon to a range, say of 0.25 to 0.35 per cent and the chrome up to 1.10 to 1.25 per cent and in so doing the purpose of the universal steel is defeated.

Therefore, a systematic and logical search of the periodic system was undertaken to find if possible the element or elements which added to steel would furnish an alloy fulfilling all the specifications. Such an ideal alloy steel, to quote the metallurgist of one of our largest automobile manufacturers, would have to show the following characteristics.

The alloying element used in its manufacture must be readily obtainable and the supply practically inexhaustible. It also must be capable of developing readily at least our present minimum physical properties and preferably something better. It must not be subject to monopoly or patent litigation. It must be so produced at the mill that its percentage of rejections due to seams, segregation and pipes is under 2 per cent of the finished bar. It must forge readily and flow easily at a temperature of 2100 to 2550 degrees Fahr., thus reducing the percentage of forgings which are thrown out for not filling out the dies and other forging defects. It must have a wide heat treatment range and must be as fool proof as possible in order to eliminate the necessity for elaborate control to produce well heat treated forgings. It must possess the quality of easy and uniform machineability with no diminution of our present physical properties. It must lend itself to the water quench.

Pursuing this quest, one element after another was tried. Some met most of the specifications, some a few and some were totally unsuited. To mention a few, iridium was cast into the discard on account of its rarity, as were rhodium, platinum and other rare metals. Uranium unfortunately at that time was too uncertain in supply and too costly; zirconium, which gave some remarkable results, was too erratic in its action, at times going into solution and at other times exercising its affinity for oxygen with detrimental effects.

Finally the choice fell on a chrome-molybdenum steel. The supply of chromium is practically inexhaustible and is found in all parts of the world, while four-fifths of the world's known supply of molybdenum is contained in the United States. On the other hand, most of our nickel comes from Canada and practically all of our vanadium is imported from Peru. There was no patent litigation and arrangements have been made to prevent any in the future. This steel will forge readily, has a wide heat treatment range and possesses exceptional machining qualities, as will be shown later, and there are no unusual difficulties attached to its manufacture.

When the decision was finally made that a molybdenum steel most nearly fulfilled all the specifications for the ideal steel, its manufacture was begun. This was, as nearly as can be ascertained from the incomplete records, the introduction of molybdenum steels into the commercial, structural field.

The manufacture of molybdenum steels is no more intricate than that of any other alloy steel. The metal is supplied in two forms, either as ferromolybdenum, which contains 50 to 60 per cent of molybdenum, or as calcium molybdate, the purer form, which contains 42 per cent, the

balance being lime. The steel may be made by the crucible, electric, or open-hearth processes and the producers of the alloy state that it may be added to the charge in three ways. First, the ferro can be introduced into the bath just before the charge is completely melted and the lime has begun to come up; second, it may be added before tapping at the same time as the ferromanganese and third, it may be added in the ladle. This last named method should be avoided when possible as the liability of imperfect distribution and segregation is great. In our practice, the ferro addition is made at any time after the slag is in shape, allowing ample time for its dissemination throughout the bath.

The use of calcium molybdate, naturally, is less common but its employment is about the same, the containers being thrown into the bath through the slag. It cannot, of course, be added in the ladle. In the electric furnace the molybdate is added after the first slag has been skimmed.

No especial precautions should be taken in either pouring or rolling, except those which would be taken with any alloy steel, and it usually will be found that the percentage of product will be greater and the rejections for seams, segregation or piping less with molybdenum steel than with corresponding grades of alloy steels. This is particularly noticeable when a chrome-molybdenum steel is compared with a nickel-chrome.

At present, the use of molybdenum in quantities under 1 per cent as an alloy is covered by analyses which include straight molybdenum, chrome-molybdenum, nickel-molybdenum, nickel-chrome-molybdenum and chrome-vanadium-molybdenum steels.

The effect of the molybdenum addition in these steels is marked. The tensile properties of the steel are raised above those of a steel of similar analysis but without the molybdenum and the elastic ratio is higher. But the most impressive effect is that of raising the reduction of area with a corresponding increase in the toughness. This can best be shown by a comparison of some actual physical results as follows:

	Chrome per cent	Nickel per cent	Chrome per cent	Molybdenum per cent
Carbon	0.28	0.37	0.23	0.30
Manganese	0.30	0.70	0.50	0.70
Chromium	0.65	1.36	0.74	0.98
Nickel	3.04	3.50	2.58	3.05
Molybdenum			0.32	0.54

Elastic limit, 116,700 pounds per sq. in.; 130,000 pounds per sq. in.
Ultimate strength, 135,200 pounds per sq. in.; 142,000 pounds per sq. in.
Elongation, 19.6 per cent; 20.5 per cent.
Reduction of area, 57.1 per cent; 65.0 per cent.

In other words, the addition of less than 0.5 per cent molybdenum with lower nickel and slightly lower chrome produced an increase in the elastic limit of 13,000 and in the ultimate tensile strength of 7000 pounds per square inch, at the same time raising the elongation about 1 per cent and the reduction of area about 8 per cent.

But these are not the only advantages. In fact, considering some of the other superiorities, the gain in physical properties becomes simply a matter of interest. Molybdenum steels have demonstrated that they have an extremely wide range for practical heat treatment which is a quality of great value in these days of unskilled and careless labor, for it

means that, instead of controlling the heat treating furnaces within a very narrow range, a difference in quenching temperature of 100 degrees makes little or no change in the properties of the finished steel. This is shown in the following table, which gives the tensile results on a piece of steel containing 0.20 per cent carbon and 0.70 per cent molybdenum when quenched in oil from varying temperature and drawn at 1000 degrees Fahr. Only the grossest negligence could duplicate such a test in shop practice and yet, even if it occurred, there would be little damage done. The results follow:

Quenching Temperature degrees Fahr.	Elastic limit, pounds per square inch	Ultimate strength, pounds per square inch	Elongation per cent	Reduction in area, per cent
1600	90,400	101,600	22.0	64.2
1700	88,440	102,000	22.5	62.9
1800	89,040	103,500	24.0	65.4
1900	88,630	100,600	23.0	64.2
2000	88,800	103,700	22.0	62.3

In addition, molybdenum steel permits a higher drawing temperature in order to obtain the same physical results. For example, in the manufacture of Liberty motor crankshafts from nickel-chrome steel, the permissible drawing range, was from 1050 to 1150 degrees Fahr., but in order to meet the requirements it was sometimes necessary to quench from the drawing temperature while the average drawing temperature on the nickel-chrome-molybdenum shafts was 1150 degrees Fahr. and the physical characteristics were slightly higher than with the other steel.

To appreciate the advantages of this it is only necessary to recall that a piece of quenched steel is in a state of unstable equilibrium and that the higher the drawing temperature the nearer the approach to a state of stable equilibrium in the steel. It is a matter of inference from this point to carry the argument a step further. Fatigue is a molecular disturbance of the metal, therefore, the nearer the steel is to a condition of stable equilibrium, the higher its powers of resisting fatigue and shock. This inferential argument seems to be borne out in the case of molybdenum steels both in laboratory tests and in actual shop practice. There is a decided difference in opinion as to value of impact and fatigue testing machines, thus without arguing as to the value of these, it will be sufficient to say that in almost every case on record, molybdenum steels have had a higher impact value than similar steels without molybdenum. The following table shows the results on Liberty motor crankshafts:

	Elastic limit, pounds per square inch	Elongation per cent	Reduction in area, per cent	Brinell	Impact, foot, pounds
Specifications call for	116,000	16.0	50.0	266	34
Medium chrome-nickel steel	129,760	17.2	53.7	307	46
High chrome-nickel steel	116,700	19.6	57.1	270	61
Molybdenum steel .	130,000	20.5	65.0	303	67

Finally, there are three great benefits to the shop in the use of these steels: forgeability, machineability and uniformity of results. Taking the last first, it is remarkable what small variations appear in extended

working with these steels. There are not so many freak tests and a greater reliance can be placed on results. This quality appears in a different way in the hardening of molybdenum steels. In quenching a large section it is usual to find a variation from the center of the mass to the edges, the hardness becoming more and more progressive. The same results are obtained with molybdenum steels but to a much lesser degree, the center and the edge showing less hardness variation.

As for forgeability, the working range is wider with molybdenum steel than with other steels and it flows better under the dies. The following quotations are from the reports of two different automobile companies. "Chrome-molybdenum steel has a wider heat treating range than chrome-nickel and works better at lower temperature." Again: "It is apparent that chrome-molybdenum has a wider forging range than chrome-nickel. We had one of the oldest and best hammer men in the shop on this job and he was highly pleased with the way the steel worked. A new set of dies was used and the axle was filled out perfectly at all points, which is very unusual with chrome-nickel under the same conditions. There was no scrap in 100 axles forged."

The ability of molybdenum steels to withstand abrasion has been questioned and unfortunately no data on this particular characteristic is available. The only test bearing on the subject is that made by a shovel manufacturer in the course of an investigation preliminary to adapting a molybdenum steel for his product. In this test, which approximated as closely as possible actual service conditions, the shovels were subjected to wear and abrasion equivalent to many months of field work, and although it is impossible to quote the actual result, the molybdenum shovels withstood wear and abrasion equally as well and in most cases better than shovels made from steel of other analysis.

If there is one pre-eminent quality attached to molybdenum which overshadows all the rest of the advantages, it is that of easy machining. It is the condition which enables the higher priced molybdenum steels to compete equally with other alloy steels for, if a steel works well in the shop, it can easily overcome the handicap in price of a steel which is delicate to heat treat, difficult to forge and hard to machine. There is such a mass of evidence bearing out the truth of these claims that it is difficult to make a choice for quotation, but following are examples.

A manufacturer of automobile parts in comparing chrome-molybdenum with chrome-nickel and 3.5 per cent nickel steels in a shop test found that the chrome-molybdenum machined more easily than either of the other steels. In the case of the 3.5 per cent nickel, the chrome molybdenum, with a hardness of more than 320 appeared to machine as easily as the nickel steel with about 270 brinell. In four different operations, all that were reported on the increased life of the tools without regrinding was from 135 to 320 per cent when working on chrome-molybdenum.

Another report states that when working on chrome-molybdenum steel, the number of pieces machined without regrinding the tools was 333 per cent more than with chrome-nickel, although the brinell hardness on the molybdenum steel was about 40 points higher.

In a laboratory test the machining qualities of chrome-molybdenum and nickel-chrome steel were obtained by heat treating a specimen of each in exactly the same manner and at the same time. The physical properties of both were similar, with a slightly higher brinell on the

chrome-molybdenum. These specimens were placed in a lathe and while the feed, shape of tool and depth of cut were kept constant, the speed was increased until one or the other turned to a blue color. This occurred first with the chrome-nickel and when it did occur there was no discoloration apparent on the piece of chrome-molybdenum.

The following is verbatim from another report of one of our largest motor manufacturers: "The remarkable forging, heat treating and machining qualities of the chrome-molybdenum steel, however, which have been outlined in the first part of this report will insure increased reliability with an actual saving in manufacturing cost which will more than offset the slight increase in the cost of steel."

"It must be remembered, however, that a unique quality of this steel is the easy machineability and its consequent effect on the wear and tear of tools. A large percentage of overhead cost is accounted for by the expenditure for fixtures and cutting tools, especially the latter. We have shown that the life of cutting tools is at least 200 per cent longer when working on molybdenum steels than with nickel or chrome nickel steel and this has been true even though the brinell hardness of the molybdenum steel was higher. We have demonstrated that for a corresponding elastic limit or brinell hardness, chrome-molybdenum steel machines much more easily than the chrome-nickel and the nickel steels; also that it will machine with equal facility when treated to show a brinell hardness of about 60 points higher. This quality can be made use of in one of two ways: either by producing parts of much greater strength and possessing a higher factor of safety; or by leaving the physical properties approximately the same as with other steels and effecting a great saving in machining cost and increasing largely the production in the machining departments.

From this standpoint alone the saving in tools and increased production due to the machineability of this steel should effect the slight increase in cost of the raw material even though no advantage was derived from the properties already mentioned, such as forging quality, greater facility in heat treatment, fewer rejections and increased factor of safety.

Having covered in an incomplete way the subject of molybdenum steels in general, it might be advisable to run over hastily the specific types of steel and their uses.

Straight molybdenum steel may contain, of course, any desired carbon content with the molybdenum running from 0.20 up to 1.00 per cent but the most used types, known as MOX 1 and MOX 2, containing respectively, 0.20-0.30 and 0.30-0.40 per cent carbon and 0.60-0.70-0.80 per cent molybdenum. These particular steels are not used extensively because the benefits of molybdenum are to a large extent lost if not augmented by some other alloy, such as chrome or nickel.

Tensile results on straight molybdenum steels quenched from 1500 degrees Fahr. in oil and drawn at 1000 degrees Fahr. are:

	Elastic limit, pounds per square inch	Ultimate strength, pounds per square inch	Elongation, per cent	Reduction in area, per cent	Brinell
MOX 1	75,400	96,000	25.4	66.7	228
MOX 2	123,500	139,600	18.5	60.8	351

Chrome-molybdenum steels are divided into four types and three classes. The first class contains 0.25 to 0.40 per cent molybdenum; the

second 0.50 to 0.75 per cent; and the third, 0.75 to 1.00 per cent. Most of the molybdenum steel, however, now being manufactured falls under the first class and it is only in exceptional cases where unusual qualities are desired that the second or third classes are specified. The four types are specified as follows:

	Carbon per cent	Chrome per cent	Manganese per cent	Molybdenum per cent
Mo. 1	0.15-0.23	0.70-1.00	0.40-0.70	0.25-0.40
Mo. 2	0.23-0.30	0.80-1.10	0.50-0.80	0.25-0.40
Mo. 3	0.30-0.40	0.80-1.10	0.50-0.80	0.25-0.40
MS	0.40-0.60	0.80-1.10	0.60-0.90	0.25-0.40

These steels are by all odds the most used in regard to tonnage and are fast being adopted by automobile and tractor manufacturers, agricultural implement makers and the machinery manufacturing trade in general. At least two of the largest automobile manufacturers in this country will probably adopt this steel for use in their cars in the near future and both are planning in adopting it as a universal steel; that is, ordering a certain carbon and using the high heats for oil-quenching stock and the low heats for case-hardening. It is suitable for use in gears, axle shafts, transmission shafts, crankshafts, connecting rods, etc., in automobiles and for corresponding parts in other machinery.

One of the leading automobile frame makers in the country is just concluding some experiments on this type of steel which furnish an interesting comparison with nickel-chrome steel. Both steels were furnished in the same gages and both were heat treated alike. The nickel-chrome analyzed: Carbon, 0.26; manganese, 0.51; nickel, 1.26; and chromium, 0.59 per cent. The chrome-molybdenum steel analyzed: Carbon, 0.22; manganese, 0.43; nickel, 0.0; chromium, 0.59; and molybdenum, 0.35 per cent.

The tensile test on an 8-inch test piece 3-32-inch thick showed:

	Elasticity limit, pounds per square inch	Ultimate strength pounds per square inch	Elongation in 8 inches per cent	Reduction in area per cent
Nickel-chromium....	112,000	130,000	6.2	30.5
Chrome-molybdenum.	135,050	146,900	8.4	37.4

The frames fabricated for a 6-cylinder passenger automobile made up of carbon steel, weighed with the hangers and fittings 225 pounds, while made up of molybdenum steel with the hangers and fittings the weight was reduced to 128 pounds. The question is whether the lighter frame will have the required stiffness, the same point having arisen in the manufacture of a front axle for one of the best known cars when the weight of the axle was reduced approximately 25 per cent by the use of chrome-molybdenum steel, but the stiffness was so affected that there was a constant whip which reduced the life of the tires greatly.

The last type of steel, MS, with the higher carbon and chrome has proved to be successful for use in springs. This is one of the uses where the high drawing temperature has a peculiar advantage as it reduces the liability of breakage without diminishing in any way the resilient properties of the spring.

Nickel-molybdenum steels can contain nickel in all proportions, but the largest tonnages which have been made fall into one of three types. The NM1 type has 0.20 to 0.30 per cent carbon and the NM2 type contains 0.30 to 0.40 per cent carbon while the nickel in both cases is about 3.50 per cent. The third type contains 2.50 per cent nickel with carbon from 0.25 to 0.35 per cent.

The use of nickel-molybdenum steel was developed during the war in the manufacture of light armor for the baby tanks. The French manufactured these tanks using a heavy manganese steel casting for the turret and to protect the gun. It was thought that the excessive weight of this armor could be reduced by using rolled and pressed shapes, but the penetrative effect of the German bullet was so great that it was a difficult problem to insure adequate protection to the crew. Finally results were obtained with armor ranging from 1-4 to 5-8-inch in thickness that seemed to assure the success of the undertaking but the steel used, a nickel-chrome gave extremely erratic results under the ballistic test and machined with such difficulty that frequently the manufacturers of safes and vaults with their special tools could not touch it. At this juncture, molybdenum was substituted for the chrome in the analysis with almost incredible results. With the straight high-nickel and the nickel-chrome 76 per cent of the plates were accepted after passing the ballistic test, which included firing at the plates at a range of 50 yards with the United States armor piercing bullet having a muzzle velocity of 2800 feet per second. The addition of 0.50-0.60 per cent molybdenum to the nickel steel resulted in 99.5 per cent acceptance of plates, not to speak of the great saving made by the comparative ease of machining. Before turning to molybdenum a large percentage of the plates would crack in the straightening process. This loss differed more or less with the different analyses used, but in no case did it run below 10 per cent and it occurred even after a 400 degree Fahr. draw in oil. When a nickel-molybdenum plate was used, this crackage was eliminated and it was soon found that the dispensing with the draw did not increase the crackage to any appreciable extent or influence the ballistic test. It is unfortunate that none of these tanks reached the front sectors before the armistice, so that the results of actual service could be determined.

However, this case was not the only one of molybdenum used in actual war material for it is well known that the Germans made extended use of this alloy, particularly in their large gun tubes, where it showed a very great resistance to erosion, the bane of the artilleryman.

As for the present day commercial uses of the nickel-molybdenum steel it can replace satisfactorily the nickel steels or the nickel-chrome steels where toughness under load is required and where ease of machining is a vital factor.

During the war in the development of the Liberty motors, a nickel-chrome-molybdenum steel was used extensively for crankshafts and showed superior results. This type of steel is now known as LM and analyzes: Carbon, 0.25-0.35; chrome, 0.70-1.00; nickel, 2.75-3.25 and molybdenum from 0.30-0.50 per cent.

The last type is the chrome-vanadium-molybdenum steel which was made for use as a steel par excellence. It has all the advantages of the chrome-molybdenum with the added qualities conferred by vanadium, which are well known.

Having now covered the types and uses of molybdenum steels, it might be appropriate to add a word of explanation regarding the cost of this steel. A great many users are prone to remarks "What! Use a steel the alloy in which cost $2.50 a pound!" It is, of course an erroneous assumption to judge the cost of a steel by its alloys. It should be judged from a basis of performance, production and rejections, and viewed from this angle, a steel which costs a cent or two more a pound may be far cheaper actually than the steel whose first cost is lower. Molybdenum is not the cure-all of the steel industry. It will not make bad steel good. It can be misused and is misused today. There are places for it and there are places where it is distinctly undesirable, and, like everything new, it seems to have been either overenthusiastically received or else uselessly condemned. Only recently a gentleman stated that he thought molybdenum steel might be the very steel he was looking for. When asked what qualities he desired he modestly replied that he would be satisfied with an elastic limit of 350,000 pounds per square inch with an elongation of 20 per cent. And today we received a complaint from a customer who was comparing chrome-molybdenum with nickel-chrome and chrome-vanadium steel. His tensile results showed the elastic limit on the molybdenum to be about 40,000 pounds lower per square inch than on either of the other steels. Investigation showed that, while both the other steels had been heat treated, the chrome-molybdenum was being tested just as it was rolled.

If the buyer of steels would balance one fact with another, selecting his material on the broad basis of general fitness, doubtless there would be many more uses developed for this type of steel. But even as it is, taking instances only from the experience of one company, molybdenum has been used for such widely varying purposes as automobile parts, aeroplane motor and fuselage parts, section steel for reapers and other agricultural machines, armor plate, battering tools, such as machinist's hammers, edge tools, such as hatchets and chisels, gears, large and small, springs of all kinds, shafting for heavy and light machinery, balls for ball bearings, shovels, rifle barrels, rivet sets, and many other uses. It was in the first planes to cross the Atlantic and was used to some extent in the largest land plane ever built in this country. And it will not be long until the preliminary announcement is made of an all-molybdenum automobile in which, it is said, every stressed part will be of molybdenum steel.

SERIES OF ARTICLES IS POSTPONED

As a result of delay in securing illustrations, the series of 10 articles on the carbonizing process by Theodore G. Selleck, Chicago, and announced to begin with this issue, has been postponed until a later issue of TRANSACTIONS. "First Principles of the Carbonizing Process—A Consideration of the Fundamental Facts and Factors of the Process" is the title of the first article which will appear as soon as the illustrations are secured. Other articles in the series will appear from time to time.

A RESEARCH IN CASE CARBONIZING

By G. S. McFarland*

(A Paper Presented at Philadelphia Convention)

This paper compares 5 per cent nickel steel, a carbon steel and a chrome vanadium steel when used for case carbonizing. The steels used for the tests had analyses as follow: The carbon steel contained 0.22 C., 0.50 Mn., 0.01 P., and 0.03 per cent S. The chrome vanadium steel contained 0.19 C., 0.57 Mn., 0.008 P., 0.025 S., 0.74 Cr., and 0.16 per cent Va. The nickel steel contained 0.18 C., 0.51 Mn., 0.01 P., 0.02 S., and 0.49 per cent Ni.

The procedure was as follows: A bar of each analysis of steel was turned down to 5-8-inch diameter and nickel at suitable intervals to facilitate breaking after being hardened. For the packing the compound known as Ajax case hardening compound was used. The pieces were packed in this in a suitable box and sealed. This was placed in a furnace and slowly raised to a temperature of 1650 degrees Fahr., kept there for a period of 3 hours, and allowed to cool in the furnace over night, being opened the following morning.

The specimens were studied, physically and microscopically in three conditions: (1) As they were when taken from the case carbonizing operation; (2) after being heated to 1425 degrees Fahr, and quenched; and (3) after being heated to 1800 degrees Fahr., and quenched then reheated to 1425 degrees Fahr. and quenched. In each case the specimens were polished and etched for microscopic examination and for photographing. The accompanying illustrations are in eight series numbered to VIII, Figs. 1-24, and each series contains three microphotographs, one each of carbon, chrome vanadium and nickel steel. All the photographs in any one series are from specimens that have had identical heat treatment. The photographs of Series I, Fig. 1-3, are magnifications of 60 diameters; those of Series II, Fig. 4-6, 100 diameters; while all the remainder are 600 diameters.

Let us first consider the specimens in Condition 1, that is, as they come from the furnace. The photographs of Series I, Fig. 3, are of the samples etched with a dilute solution of nitric acid in alcohol. These were taken to show the depth to which the carbon has penetrated. It will be seen that there is little difference in the three steels. Series II, Figs. 4-6, shows the specimens after being etched with a solution of sodium picrate which colors the carbide or iron, cementite, black. In the carbon steel, Fig. 4, it will be seen that the excessive cementite is in the form of a coarse network, while in the chrome vanadium steel, Fig. 5, the network is fine. In the nickel steel, Fig. 6, we find something different, the nickel unites with the cementite to form a complex double carbide of iron, about which little is known. Series III, Figs. 7-9, is the same as Series II, but magnified 600 times. Here the differences noted before have become more marked.

Series IV, Figs. 10-12, shows photographs of the cores of the samples as they come from the furnace. The sames were etched with dilute solution of nitric acid in alcohol. In the case of the carbon steel Fig. 10, we find large crystals of well developed pearlite in the laminated condition occurring as islands in a matrix of ferrite, in other words, nearly pure iron. In the case of the chrome vanadium steel, Fig. 11, we still find the islands of pearlite in a matrix of ferrite, but here the pearlite is not so

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SERIES I

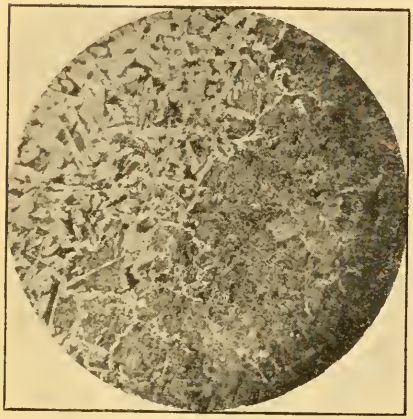

Fig. 1—Carbon Steel x 60

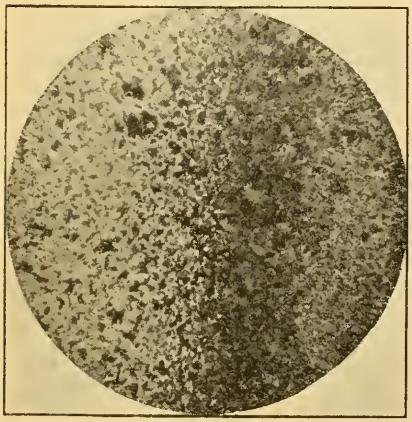

Fig. 2—Chrome Vanadium Steel x 60

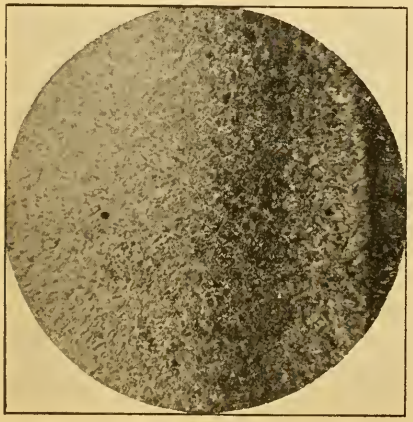

Fig. 3—Nickel Steel x 60

SERIES II

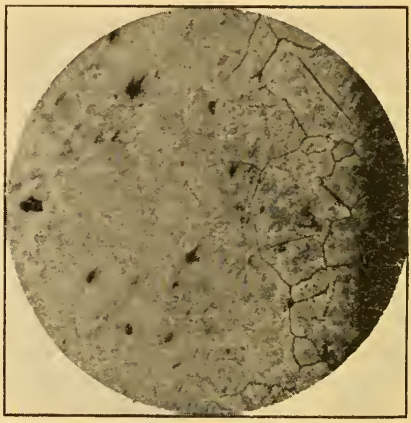

Fig. 4—Carbon Steel x 100

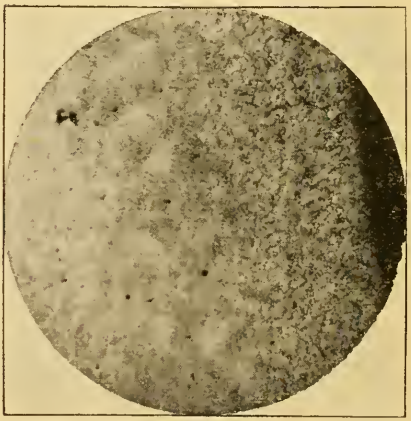

Fig. 5—Chrome Vanadium Steel x 100

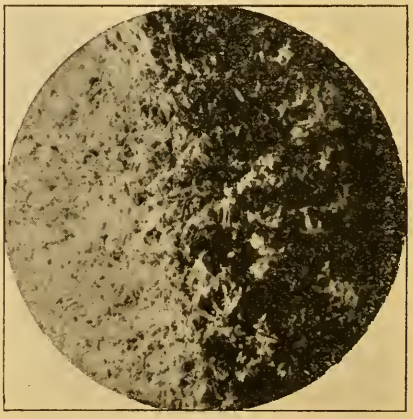

Fig. 6—Nickel Steel x 100

well developed; also the pearlite particles are smaller and greater in number. This will be pointed out as an advantage a little later. In the nickel steel, Fig. 12, we find that the structure is much finer than in the preceding two steels and is all broken up. It seems to be a mixture of lamellar pearlite, granular pearlite and ferrite.

The following results show brinell and shore hardness of the steels in Condition 1, as they were taken from the furnace.

Specimen	Brinell	Shore
Carbon	99	18
Chrome Vanadium	121	21
Nickel	174	23

Let us now consider the steels in Condition 2, that is, hardened at 1425 degrees Fahr. Samples of each of the steels were clamped together in a frame to insure identical treatment, put into a small gas furnace and slowly raised to 1425 degrees Fahr., soaked at that temperature a few minutes, and quenched in an abundance of cold water.

We will first consider the condition of the metal in the cores, taking them in the usual order. Series V, Figs. 13-15. In the carbon steel, Fig. 13, we see that each island of pearlite has been converted into martensite surrounded by a border of a darker material, which is troostite. The cooling was not sudden enough to remain all the martensite in the original form, thus part of it decomposed into troostite and was retained as such. We see the ferrite matrix the same as in the specimen that had not been treated. The reason the matrix of ferrite and the pearlite of the original steel did not dissolve in one another, and when quenched give a uniform structure throughout, is that the highest critical point of this steel lies in the neighborhood of 1700 degrees Fahr. and until that temperature was reached a complete solution could not take place. In the chrome vanadium steel, Fig. 14, we see somewhat the same result as in the carbon steel. The islands of pearlite have been converted into martensite surrounded by a matrix of ferrite, but here we have no troostite precipitated. In the original steel, the particles of pearlite being smaller and of greater number than in the carbon steel, we should expect to find a closer and stronger looking steel after being quenched than was the case with the carbon steel, and indeed such is the case.

It is with the case of the nickel steel, Fig. 15, however, that we see the most striking result. Here the particles of pearlite and the ferrite matrix have completely dissolved in one another, and upon quenching a fine grained structure consisting wholly of martensite, has been retained.

To one not familiar with metallography, the results of Condition 2 tabulated below will present the physical properties in a striking manner.

Specimen	Brinell	Shore
Carbon	235	29-30
Chrome Vanadium	262	36
Nickel	402	50-52

Let us now consider one of the cases after having received the above treatment, namely, quenching from 1425 degrees Fahr. and illustrated by Series VI, Figs. 16-18. In the carbon steel, Fig. 16, we have a good martensite structure, but shot through with a coarse network and needles of excessive cementite which, of course, form places of weakness. In the chrome vanadium steel, Fig. 17, we have a still finer martensitic structure than the preceding. Here the excess cementite is in the form of a fine network com-

pletely breaking up the mass. In the nickel steel, Fig. 18, we have a fine martensitic structure throughout with no excess cementite, probably due to the fact that the complex double carbide of carbon nickel and iron referred to above is completely retained in solution. It will be seen from the illustration that the structure is homogeneous throughout with no planes of weakness such as are contained in the other two steels.

As the brinell test is not satisfactory on case hardened articles, only the shore hardness for this case is given.

Specimen	Shore
Carbon	80-84
Chrome Vanadium	85-89
Nickel	70

In the above we see that the nickel core has dropped behind the other two. By experiment this was shown to be due to too high a hardening temperature. A temperature of 1325 degrees Fahr. and quenched gave results comparable to the other two, shore 85-87.

We now come to Condition 3, in which the specimens were first heated to 1825 degrees Fahr. and quenched in cold water; then reheated to 1425 degrees Fahr. and quenched in cold water.

Let us first consider the condition of the metal in the cores, as shown by Series VII, Figs. 19-21. In the carbon steel, Fig. 19, we find that a partial solution of the martensite, troostite and ferrite has taken place, but the structure is far from perfect and leaves much to be desired. However, it is perhaps as good a structure as is usually obtained in regular working conditions with a like grade of low carbon steel. We find that the chrome vanadium steel, Fig. 20, is a great improvement over the carbon steel, there being but few particles not in solution, the structure for the most part being finely martensitic. In the nickel steel, Fig. 21, everything is in solution as before and the structure is martensitic, but of a coarser texture than that of the steel having received but the single treatment.

The shore tests of this case are as follows:

Specimen	Shore
Carbon	32
Chrome Vanadium	38
Nickel	48

While a comparison to those steels in Condition 2 show that there is a slight increase in hardness for the carbon and chrome vanadium steels, while there is a corresponding decrease in that of the nickel steel. The brinnel tests for these samples are not given owing to the fact that the samples are too small to make the tests of value.

In comparing the cases of these steels as last treated, Series VIII, Figs. 22-24, we find that the excessive cementite in the carbon and chrome vanadium steels, Figs. 22 and 23 respectively, the structure has been coarsened somewhat. The shore tests are as follows:

Specimen	Shore
Carbon	80-83
Chrome Vanadium	80-83
Nickel	80

The double treatment as applied to these steels increases the useful properties of the carbon and chrome vanadium steels by toughening their cores, and decreases from those of the nickel steel by weakening its core. The hardness of the cases are about the same in all cases.

SERIES III

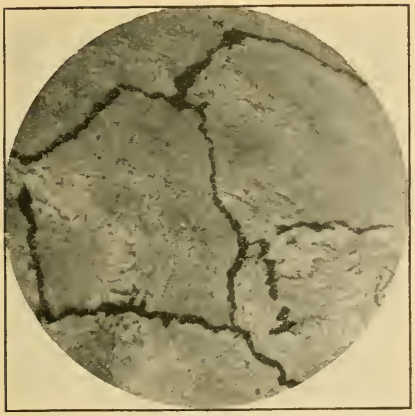

Fig. 7—Carbon Steel x 600

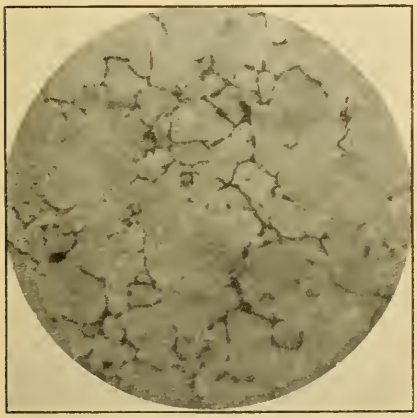

Fig. 8—Chrome Vanadium Steel x 600

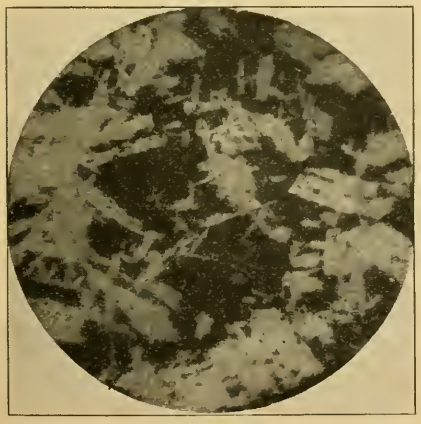

Fig. 9—Nickel Steel x 600

SERIES IV

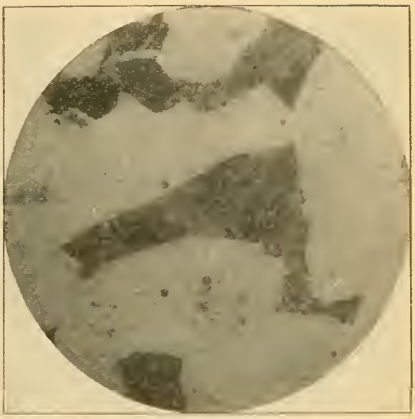

Fig. 10—Carbon Steel x 600

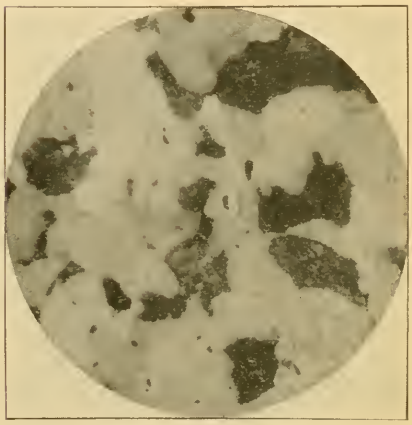

Fig. 11—Chrome Vanadium Steel x 600

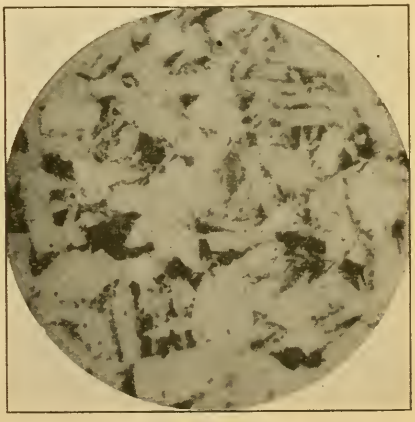

Fig. 12—Nickel Steel x 600

SERIES V

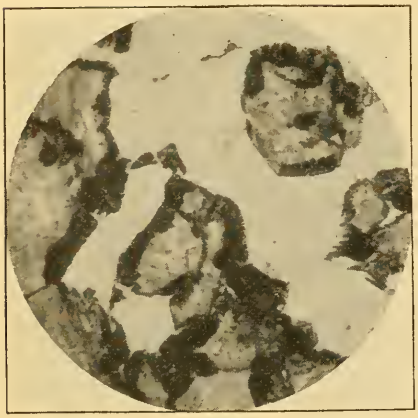

Fig. 13—Carbon Steel x 600

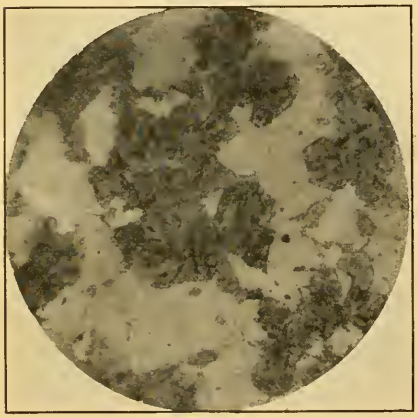

Fig. 14—Chrome Vanadium Steel x 600

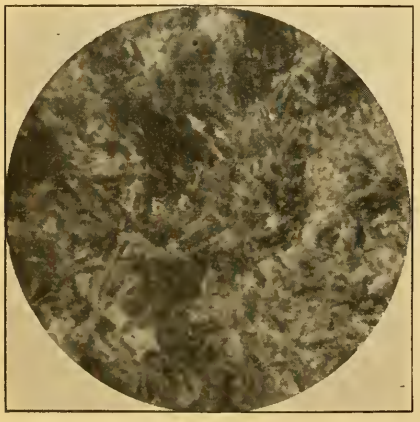

Fig. 15—Nickel Steel x 600

SERIES VI

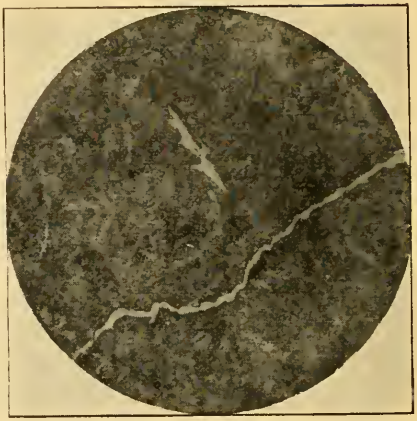

Fig. 16—Carbon Steel x 600

Fig. 17—Chrome Vanadium Steel x 600

Fig. 18—Nickel Steel x 600

I think it will be seen that for ease of working, that is a single heat treatment, and for its higher physical properties, the nickel steel is superior to the other two.

The steels in this research have been treated alike throughout at purely arbitrary temperatures, and there is no doubt that the physical properties obtained could be improved upon by a research on any particular steel, finding out its separate needs and peculiarities as regards the packing material, the length of time of the carbonizing, and the temperature or temperatures to which it is heated before quenching.

DISCUSSION OF MR. McFARLAND'S PAPER

MR. HOLBING: I would like to know whether those physical properties obtained are not rather high. They are rather unusual, particularly to obtain 70,000 pounds per square inch elastic limit from case hardening of a straight carbon steel.

MR. McFARLAND: Those steels after experimenting are found to be practically the ideal condition. They are a little better than the commercial.

MR. HOLBING: It is not possible in some of the carburized cases.

MR. McFARLAND: I have ground those off sufficiently. I think this 5 per cent nickel steel is a remarkable steel. Along with my physical tests on those I have carried on a cold bend test. I have taken all these steels, first quenched at 1100, 1200, 1300, 1500, and on up to 1800 degrees, Fahr. pulled them and obtained a decided difference in the physical properties by watching this cold bend test. The specimen I have standardized upon for this test is about 6 inches long and ¾-inch in diameter and after treating, carbonizing, and putting through the regular process, I grind the case off and then with a bending device which I have devised have applied it under an Olsen or a Reilly test, so all specimens get the bend test.

MR. HOLBING: Could I ask what was the carbon content of that steel?

MR. McFARLAND: 0.22 per cent. I got these fairly close together; carbon 0.22 per cent, chrome vanadium 0.19 per cent, and the nickel steel 0.18 per cent, so there is only 3 or 4 pounds difference in them.

MR. HOLBING: It occurred to me that the chrome vanadium and the nickel steels were rather high too; 70,000 pounds per square inch was beyond the bounds of heat treated 0.20 carbon steel.

MR. McFARLAND: I will agree with you that commercially we would not get quite as high test as that.

MR. HOLBING: We have had some elegant steels, but we have never been able to get anything like that.

MEMBER: Do I understand the gentleman to say he can not get 70,000 pounds per square inch on that steel?

MR. HOLBING: Yes.

MEMBER: I have obtained 90,000 pounds per square inch.

DR. HARTZELL: Mr. Lane of the York Mfg. Co. requested me to ask a question for him. He asked me the same question and I could not answer it. The point is not directly bearing on your paper, but indirectly so, but is this: Is it possible to select a steel commercially with some additional alloy or alloys which may be cased, air quenched, and be hard?

SERIES VII

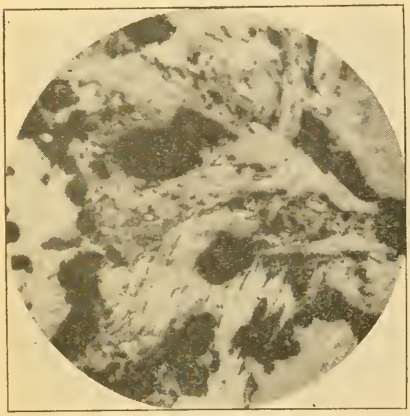

Fig. 19—Carbon Steel x 600

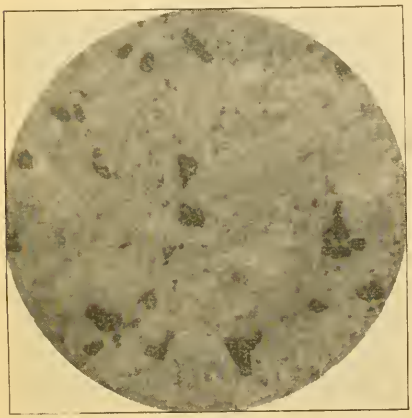

Fig. 20—Chrome Vanadium Steel x 600

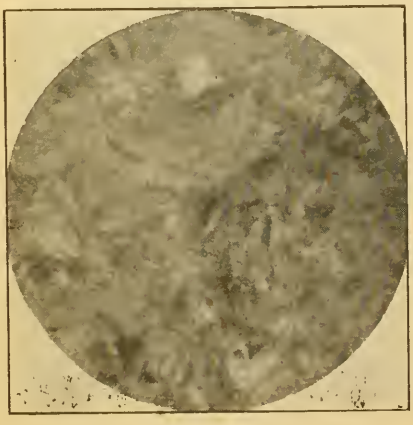

Fig. 21—Nickel Steel x 600

SERIES VIII

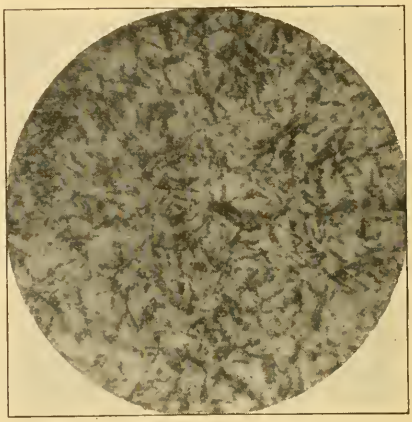

Fig. 22—Carbon Steel x 600

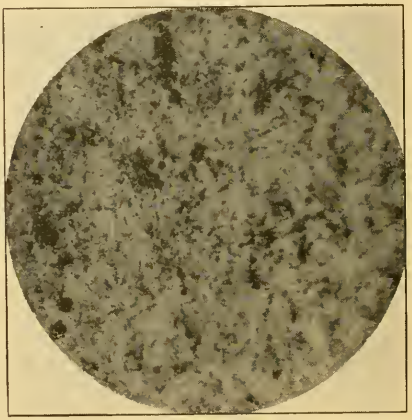

Fig. 23—Chrome Vanadium Steel x 600

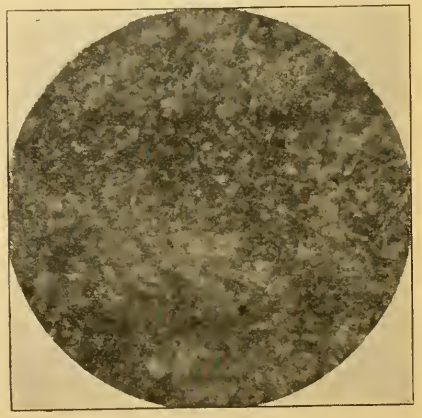

Fig. 24—Nickel Steel x 600

MR. McFARLAND: Yes.

DR. HARTZELL: Mr. Lane would like to have you explain.

MR. McFARLAND: I have been experimenting with nickel steels as high as 9 and 10 per cent, and from tests that I have made we have obtained about a 9 per cent nickel steel with a 0.15 to 0.20 per cent carbon content which air hardens. When you put a scleroscope on that, it will show only a hardness of about 30 or 35 feet that is hardly a machine tool and as far as the work that I have done upon it is concerned, it is almost impossible to commercially anneal that so it can be machined.

MR. HARPER: I would like to inquire of the speaker if the nickel steel which, after quenching, gave a lower brinell hardness than the straight carbon steel would show an increase in hardness after a draw at a relatively low temperature?

MR. McFARLAND: I have not determined that.

MR. HARPER: I wondered if it would also show an increase in hardness after drawing.

MR. McFARLAND: You mean quenching at a temperature of 1325 to 1350 degrees Fahr.? It will on the case, but the structure of the core is really below the recalescent point of the steel itself, and you would not get the physical properties of the core.

MR. HARPER: It occurred to me there might be an increase in hardness there.

MR. McFARLAND: I have some interesting figures on the physical properties of these 5 per cent nickel steels quenched at different temperatures in conjunction with the cold bend test that might be interesting to some. I will be glad to show those to anybody who would like to see them. I believe a great deal can be obtained by means of this cold bend test. In connection with the working along of the physical properties much can be determined. You get a point in there where you can get an exceedingly high elastic limit and great ductility, as shown by the bend test.

MR. STRENGER: I would like to ask if you can give us an explanation of just why copper plating prevents carburization?

MR. McFARLAND: I cannot.

CHAIRMAN: Maybe somebody here would like to ask the question why it does not at times. (Laughter).

A NOTE ON DOUBLE PREHEATING HIGH SPEED TOOLS FOR HARDENING

By A. E. MacFarland*

(A Paper Presented at Philadelphia Convention)

A few years ago my friend and associate, Arthur G. Henry, called my attention to double preheating high speed tools before subjecting them to the high temperature of the hardening furnace. Since that time a rather comprehensive study has been made of various methods of hardening high speed steel, which has brought out strong points in favor of double preheating.

The practice of hardening high speed steel tools using a double preheating treatment has been outlined in several unpublished addresses and papers by the author somewhat as follows:

Three furnaces are used for the hardening operation, being maintained at respective temperatures of 950-1000 degrees Fahr.; 1500-1600 degrees Fahr. and 2300-2375 degrees Fahr. After the tools are finished, machined and annealed to relieve all strain, they are placed in furnace No. 1 on suitable jigs to raise them from the hearth of the furnace and to enable them to heat more uniformly. This furnace may be loaded to capacity and is used as a stock furnace to supply furnace No. 2.

Furnace No. 2 is the second preheating furnace operating at approximately 1525 degrees Fahr. The tools on their jigs are transferred from furnace No. 1 to furnace No. 2, allowing them to remain subjected to a temperature of 1525 degrees for a period of time sufficient to thoroughly and evenly saturate the tool being hardened. Care should be taken not to leave tools for too long a period of time in the second furnace and for this reason it is not advisable to have more than three good sized tools in this furnace at one time.

Furnace No. 3 is the regular high temperature hardening furnace and is supplied with tools from the second furnace. The tools are allowed to remain in the high temperature furnace operating at about 2325 degrees Fahr. for a predetermined suitable length of time, which has been found to impart the most desirable properties to the tool. Tools are quenched from this furnace usually in oil and subsequently drawn to 1050 degrees Fahr. in either lead pot, saltpeter pot, or electric furnace.

The practice briefly outlined above constitutes what large manufacturers of small tools have found to give best results in hardening high speed tools. Before going into the reasons and advantages to be derived from the double preheating operation, a short discussion of decarbonization is probably advisable.

Decarbonization is the reverse of carbonization. When a piece of steel is carbonized it is packed in a suitable mixture, which, upon being heated, transfers carbon from the mixture to the surface of the steel. Decarbonization, on the other hand, consists in extracting the carbon from the surface of the steel being treated, and is manifested by a soft surface layer of metal which will not harden due to the absence of carbon. Decarbonized surfaces can usually be detected by a file after hardening,

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by inspection of the fractured surface, or by microscope examination. None of these tests are infallible although usually adequate for inspection purposes. The best test for decarbonization consists in analyzing the chips removed from consecutive layers of the steel 0.005 of an inch thick. These chips from the separate layers can easily be analyzed for carbon and any differenes noted in the surface carbon content to that of the body of the steel.

Decarbonization causes considerable trouble to the tool hardener and in order to prevent the same it is necessary to inquire into the basic cause of the phenomena. Decarbonized surfaces are caused by scale, therefore, it is advisable that all tools exhibit surfaces entirely free from scale before hardening. This is not so necessary in the case of tool bits, or roughing tools, which are ground to shape after being hardened as decarbonized surfaces are easily removed by the emery wheel. In the case of circular forming cutters, hobbs and intricate milling cutters, it is very necessary as the grinding allowances on these tools are usually small and a decarbonized surface absolutely ruins the tool for cutting purposes. If the formation of scale can be eliminated or reduced to a minimum the danger of decarbonization of surface is lessened.

Reducing atmospheres in furnaces tend to reduce the tendency toward scaling, but when steel is once scaled, a reducing atmosphere is more apt to produce decarbonization of surface than an oxidizing atmosphere. On the face of it, this statement seems almost contradictory, but its truth will be realized when one considers the chemistry involved. Scale as scale will not extract carbon from the surface of the steel in an oxidizing atmosphere, however, when a reducing atmosphere is maintained the scale is reduced from iron oxide to metallic iron and the atmosphere of the furnace works in connection with the steel just under the scale, which gives up part of its carbon to reduce the scale to the iron. In this way a decarbonized surface is formed and is proportional to the nature of the scale, the quantity of the scale, and the temperature of the furnace. Steel does not scale rapidly until it has attained a temperature of about 1200 degrees Fahr. Therefore, it can be heated safely for relatively long periods of time at a temperature between 950 and 1100 degrees Fahr. without damage due to scaling.

This is one of the very important advantages double preheating has upon a single preheating operation prior to hardening. Placing a cold tool in the preheating furnace at a temperature of 1525 degrees Fahr. subjects the tool to a scaling temperature under ordinary furnace conditions and the outside of the tool will exhibit a relatively heavy scale before it is up to the required temperature. On the other hand, if a tool is preheated to 1050 degrees Fahr. before being placed in the 1525 degrees Fahr. furnace, it will require a correspondingly shorter time to come to a temperature with a corresponding decrease in the amount of the scale form.

Double preheating also increases the production of the tool hardening plan inasmuch as it cuts down the time necessary for preheating.

It is well recognized that heavy masses of high speed steel in the form of tools require exceptional care in heating. If heated too rapidly these tools will develop strains which cause them to crack. Double preheating, therefore, decreases the tendecy for large tools to crack in the

hardening process as it provides a method of more gradually heating them before subjecting them to the high temperature of hardening.

In outlining this method it is not desired to convey the impression that good results cannot be obtained by the single preheating treatment in common usage as there is too much of the personal element involved in the hardening of high speed steel to set down hard and fixed rules to apply to every plant and each individual. Neither is it desired to convey the impression that high speed steel is especially complicated in its treatment. It should be emphasized, however, that the more care and attention given to the gradual heating of high speed steel tools before hardening, the better will be the performance of the tools in actual use.

The author is personally acquainted with several cases in large size tool rooms producing tools in quantity where double preheating has spelled the difference between failure and success.

DISCUSSION OF MR. MacFARLAND'S PAPER

MR. REARDEN: Why do we get an apparent increase in decarbonization from the furnaces equipped with the one pipe system than we do from furnaces equipped with the two?

MR. MACFARLAND: You mean burners? Well, the question of furnace design, of course, enters into the decarbonization quite extensively as the atmosphere of the furnace is more or less determined by its design. I am not exactly familiar with what you mean by the two-burner or the one-burner type of furnace. I am satisfied in my own mind that a furnace can be designed for a satisfactory hardening of high speed steel with just one burner, but it is a question of whether the tools are subjected to a blast of hot furnace gases or whether they are protected rather well from hot furnace gases. I think that more important in considering decarbonization.

MR. REARDEN: My own experience is, that taking the one pipe with practically no control, you cannot get what I call a drier heat. That is my notion. You are getting more decarbonization than you would with the drier flame, as I put it myself.

MR. STAGG: I regret very much that Prof. Henry Howe is not here. In Professor Howe's absence, and having been one of his students some time ago, I want to say something which I know Professor Howe would say were he here. I am quite sure that Professor Howe when he thinks of the effect of the removal of carbon from the outside would characterize that effect as decarburization rather than decarbonization. Or, the reverse, as carburization and not carbonization. That word I hear misused wherever I go, and I am trying to bring it out so we will all talk in the same terms and talk correctly. There is also one question I would like to ask Mr. MacFarland. He mentioned conditions for the production and the prevention of decarburization. I wonder if he has done any work along gas analyses which will give us some information as to the actual analyses of gases, either from an oil, gas or coal furnace which will be ideal for the prevention, and which will be ideal for the formation, of decarburized surfaces.

MR. MACFARLAND: I have done nothing along those lines. I have not gone into the thing quite so extensively as that, Mr. Stagg. Have you done any work along those lines?

MR. STAGG: Not enough so that I would want to say anything about it here. (Laughter).

MR. SMITH: With reference to Mr. Rearden's statement about the one pipe system as against the two pipe system, you can get equal results, well, rather, I won't say you can equal results, but you will find, I believe, that you can get better results, with the one pipe system than you can with the two, because you will eliminate the mixtures of air and gas. Take the mixture of air and gas out of the operator's hands, and once you set your mixtures correctly, getting you flue gas correct by the analysis of the flue gas, seeing that you get no free oxygen and no free carbon monoxide, your flue gas will always remains the same. From experiments of the Surface Combustion Co., I believe absolutely no free oxygen and no carbon monoxide gas in your furnace atmosphere is the ideal condition.

MR. MACFARLAND: I feel sure, Mr. Johnson, that you have something to say about decarbonization.

MR. JOHNSON: Mr. Chairman, as Mr. McFarland says, the steel heating furnace having a truly reducing atmosphere would cause decarbonization and scale on the steel when you put it in. The scale instead of coming away clings more tightly and absorbs carbon from the surface of the metal, whereas if the temperature is oxidizing to a certain extent the scale instead of clinging to the steel falls away, because of the formations underneath. As to the atmosphere of the furnace, one has to consider that carbon dioxide there will cause decorbonizations. I made some experiments some years ago along these lines and one has to be careful how they shut the air away for if he shuts the air away he stands a good chance of having some soft spots and decarbonization.

Of course, everybody knows it is not a good thing for a sharp oxidizing flame to impinge directly on the surface of the metal. But we have to guard against conditions approaching reducing conditions just as much. That is one reason a hardening furnace using carbon resistor face is rather a risky furnace to use in those high temperatures. Then I have often wondered about the matter of sweating tubes, whether that is not often a source of trouble—when it is necessary to go so far as to cause sweating on the tubes. I think that has its bearing. Give it a little more time on such extreme heats.

HARDENING HAMMER DIE BLOCKS

By R. B. Kerr*

(A Paper Presented by Title at Philadelphia Convention)

Since the introduction of the modern drop forging hammer, the problem of producing and successfully heat treating large dies to get the maximum of service with a minimum of loss, has engaged the attention of steelmakers and steel treaters alike.

Early in the game it was found that the percentage of loss from hardening from various causes was heavy. Flaws or pipes in the interior of the blocks resulting from improper casting or forging; steel of too high or irregular carbon content; and more especially inadequate tempering room equipment, are among the chief causes of failure. The unfortunate hardener too often is made the goat for the sins, mostly of omission, of both the steelmaker and the shop foreman.

*Foreman, heat treating department, John Deere Harvester Works, East Moline, Ill.

To get around possible loss in heat treating, various kinds of alloy and socalled heat-resisting steels have been tried, with more or less success. Now it is generally conceded, however, that a good sound steel of medium carbon content, when properly hardened, gives the best all round service. The methods suggested herewith for accomplishing this have been in successful use by the writer for a number of years and are offered not with any idea that they are perfection or the only way, but with the hope that they may be helpful.

While die blocks can be heated successfully in either coke or oil furnaces or even in the smith's forge, a gas heated furnace of the oven type is by far the most convenient and satisfactory for this work.

Coke makes a nice clear fire of fairly simple regulation, and with a skillful heater in charge, good results can be obtained. An objection to its use is the frequent presence of impurities, particularly sulphur.

When heating dies the considerable air pressure required to burn fuel oil, makes necessary the most extreme care to prevent scaling or surface decarburization in the parts to be treated. The furnace, therefore, should be of the muffle type, the heating chamber completely inclosed, or if this is not available, the die should for protection be packed face down in a gas tight box of suitable size half filled with charcoal, and the whole thing heated up. If the piece to be heated is of considerable size, the packing box should be made with hinged ends which fold down out of the way so that the die can be lifted out readily by grab hooks or a sling. This "safety first" method entails some extra work and inconvenience, but the results justify it. Personally, the writer can testify through considerable experience that it is better to go to some extra trouble to assure success, than to have an opportunity later on to frame up excuses that will pass when asked to explain "how it happened."

It might be said in passing that this method of pack hardening is excellent for heating dies and tools of nearly all descriptions. The parts come out of the packing box uniformly heated with a surface perfectly free from scale and in the best possible condition for hardening. The process is an old and successful way of heating steel. It deserves to be more widely known and practiced.

Whatever the type of furnace used or the means employed the all important thing is to get a good heat on the die; a thorough slow soaking, uniform heat, for upon that depends to a great extent the success or failure of the operation. Particularly for the benefit of the younger steel treaters it may be said that thorough careful heating, more especially when handling comparatively large blocks of steel, is most essential. It is the author's opinion, based on a long and varied experience in hardening steel, that more dies and tools are ruined by careless heating than from all other causes combined.

For heating, a gas-fired, oven furnace of ample capacity should be used as being most convenient and suitable for the job. If the oven is already hot so much the better, if not, bring it up pretty well before putting in the work. Dies of any description should not be put into a cold furnace. Nothing is gained in time, and besides some chances of surface decarburization are offered with a rapid rising heat.

Place the die in the furnace face down, unless the nature of the impressions makes this impossible; in which event it is good practice to protect the surface from possible gases by laying a closely fitting piece of

asbestos or sheet steel on top while heating. As another precaution, if the die is of considerable size and the impressions are deep or irregular, it is well to bring it up to a dull red heat, about 1300 degrees Fahr. and let it partly cool off in the furnace before taking the hardening heat.

Heat slowly and regularly. The time required of course will vary in proportion to the heating area of the furnace and the size and shape of the piece to be treated. Usually three to five hours are required for drop forging dies of average size. The most important point is, as already mentioned, to get uniform heat throughout the piece. One of the most valuable assets a steel treater can have is the ability to judge or sense correctly when a large block of steel is heated properly throughout. While a pyrometer or other reliable heat measuring device is a valuable aid and guide, it is not everything, neither can it indicate what is going on inside the mass, and the writer has learned from experience that outward appearances in steel die blocks, as in many other materials, are often times deceptive. The average grade of hammer die steel will harden nicely at around 1450 degrees Fahr. and the heat always should be held stationary for at least 15 minutes before removing the die from the fire.

The quenching tank should be of ample size and the water supply arranged so that it can be forced upward against the face of the die with considerable force and volume, using an overflow pipe of sufficient size to take it away. In most cases clean fresh water is all that is necessary, but if extreme hardness is required or if the water is soft or muddy, river water as an example, the addition of a little salt will sharpen it. If this is done, a loose woven sack filled with salt and suspended in the tank, will be found most convenient. Place a resting rack across the top of the tank, arranged at sufficient depth so that the impressions on the face of the die will be well covered with water when the die is laid on it. On flat surfaced dies or on dies in which the impressions are shallow, a depth of from 1 to 1½ inches is about right.

When all is ready get the piece out of the fire. If there are any dangerous looking corners or sharp projections that do not need to be hard, partly cool them off with a water jet or piece of water soaked waste to prevent chipping. Place the die on the resting rack face down and turn on the water. If the piece is wide or flat, prevent warping or crowning by keeping the back slightly cooled off; just enough water and no more. Run the hand over the face frequently to find how it is cooling off.

Never let a die cool off entirely in the water. Whenever the face is cool enough to prevent the temper from drawing, get it out as quick as possible and lower it into the oil tank. Keep the die moving or agitate the oil.

The temper should be drawn slightly on all hammer dies, both to relieve strains and to give them resiliency or spring, as well as for better wearing qualities, and the drawing should be begun immediately; even before the die is quite cooled off. If there is an oil tempering furnace at hand large enough, get the piece into it. Raise the temperature to around 400 degrees Fahr. and hold it there for an hour or so. If for any reason this method cannot be used, swab the die with light machine oil and place in a furnace partly cooled off. Leave it there until the oil begins to flash, then remove and allow it to cool off in the air.

A die should never cool off entirely in the water. When a mass of steel at the hardening temperature is plunged into cold water, the grains

in its outer surface immediately become set and rigid. A certain amount of contraction and shrinkage also takes place, partly because of the change from high to a low temperature and also because of the hardening of the metal. The amount of this shrinkage is in exact proportion to the surface area of the mass being treated; the greater the area the more the shrinkage. If this change took place all the way through there would be no trouble; but it does not. In the first place, the interior of the piece cools off much more slowly than the outside and secondly, the setting of the grains due to hardening extend in a depth of from only ¼ to ½ inch at the most. This suddenly chilled outer layer is consequently being forced against the softer mass inside with an enormous pressure, causing distortion and strains which become more marked as the piece cools off. When the temperature recedes to a certain stage, governed partly by the temperature of the quenching water and the air, a violent action takes place. This is the danger point. The friction created by the molecules striving to adjust themselves to the new conditions generates heat inside; heat means expansion, and unless this condition is offset promptly by heat applied to the outside to relieve the strains, the die, particularly if a large one, has about an even chance of bursting open. Whether it does or does not, the strains are there and are just as liable to manifest themselves in service later on as they are to appear immediately after hardening.

Allowing the dies to remain, in the water too long and failure to draw the temper promptly after hardening is responsible for considerable breakage. This is partly due to the lack of proper equipment, and also to the fact that the principles involved are not so generally understood as they might be even among steel hardeners. This heat generation by friction, or as some might call it, molecular reaction inside of a body of steel, is no pet theory, but the author has noted its effects during many years of close observation and practice in the heat treating of steel. Furthermore, he believes it will be found in line with the natural laws governing cooling bodies. Be that as it may, the writer has found this method of hardening dies a success and can recommend it to steel treaters who are having trouble.

BLAST FURNACES AND THE MAKING OF PIG IRON

By Arvid Anderson*

(A Paper Presented Before the Hartford Chapter)

In producing steel from iron ore the manufacture of pig iron is the most important intermediate step. In late years a number of men, for example, Yates, Chenots, Ellerhousen, Broling-Lang, Cassett, Siemens, Blair and a few others have tried to manufacture steel directly from the ore, but these attempts have not met with any success and at present are only of historical value.

The only practical method of manufacturing pig iron is by the blast furnace; no man can really claim the honor of being the inventor of the blast furnace, for as far back as the history of iron and steel goes the manufacturer and furnaces in which he charged layers of fuel and iron ore. The product of the first furnaces was only a sponge-like lump of more or less pure iron and a large percentage of iron went into the slag.

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At the beginning of the fourteenth century an agreement was made between the European nations that a prisoner of war could be exchanged for another, or that the prisoner could be bought free. This brought about a labor shortage and the iron manufacturers had to look to some other source for power to drive the bellows of the furnaces. As a result their minds turned to the water wheel.

By installing the water wheels the bellows could be made larger and a more even pressure on the blast was obtained, which produced partly melted iron. The producers at first worried about this molten iron, noticing that the initial product was less and very hard and steel like, though after the refining process the final product was larger than by the old type furnaces. Thus, soon all furnaces as far as possible were changed over to produce molten iron. Where the first blast furnaces were really built is still a source of argument, but so far as known the first furnace was built in Sweden the early part of the fifteenth century, though Professor Beck claims that the first blast furnace was really built in Germany in the middle of the fifteenth century. In a deed dated 1431 the King of Sweden gave to one of his generals all the income from a certain blast furnace. The first furnace constructed after drawings was built in Sweden in 1573 and was only 10 feet in height.

At the beginning of the sixteenth century this method of manufacturing iron was used only in Sweden, the western part of Germany and the eastern part of France. When the blast furnace first came to Belgium is still unknown although after Carl of Burgund lost in battle in 1496, he gave orders to his soldiers to destroy all blast furnaces. In France this method became general after Carl XI called in men from Germany to build furnaces. The first blast furnace in England was also built by Germans in 1540 for the manufacture of guns and ammunition. In the United States the first furnaces seem to have been built in the early part of 1700.

Blast furnaces can be divided into two classes, charcoal and coke furnaces. The charcoal furnace is little used in the United States. Of about 465 furnaces operating in this country a year ago, only 40 were charcoal fired, and in 1916 there was produced in this country about 39,000,000 tons of coke pig iron as compared with only 370,000 tons of charcoal pig iron, this showing that charcoal blast furnaces are of little interest to the people of the United States.

The modern blast furnace consists of a tall cylindrical stack lined with an acid fire brick and built on a very deep and solid foundation of stone and fire brick. The American type of furnace ranges from 80 to 100 feet in height. The stock or furnace proper which is usually round consists of three divisions. At the bottom is the hearth or crucible, cylindrical in shape and about 8 feet deep; above it is the bosh, about 12½ feet high, whose diameter flares out from that of the hearth about 16 to 22 feet making it the largest inside diameter of the furnace at any point. From the top of the bosh the walls converge gradually to the throat which is the very top of the furnace. The entire furnace is usually inclosed in a steel jacket and up to a certain point by cooling plates of bronze or other metal through which water circulates. Water is also sometimes allowed to flow down the outside of the furnace. The section above the bosh is supported on a mantle and column.

Through the lining of the furnace, just at the top of the hearth, extend the tuyeres, 8 to 16 pipes having an internal diameter of 4 to 7 inches through which hot air is blown to burn the coke and furnish the heat for the

smelting operation. The tuyere notches or openings through which the tuyere pipes enter and the tuyeres themselves are surrounded by hollow bronze rings in which cold water is flowing to prevent them from melting on the inside. The number of tuyeres and their size depend on the diameter of the bosh and the volume and pressure of the blast. It must be small enough so that the effect of the blast can reach the center.

On the side of the furnace and 30 to 40 inches below the level of the tuyeres is the cinder notch which is protected by a water-cooled casting. It is closed by forcing an iron plug into it around which the slag cools and closes up the opening. The slag must not be allowed to rise above the level of the tuyeres. In the front and at the very bottom level of the hearth or crucible is the iron tap hole from which all the liquid contents of the furnace can be drained. This is a large hole in the brick work and is closed by ramming in several lumps of clay.

The hottest part of the furnace is near the tuyeres and a few feet above them and at this point the most water for cooling is needed to prevent the brick work from melting. The brick work also is protected on the inside by a thin layer of deposited carbon caused by the effect of the strong reducing conditions present in the furnace. These conditions are due to the excess coke producing a deposit of finely divided carbon which in turn is covered by a cinder slag which sticks to it. This combination is effective in protecting the internal brick work.

At the top of the furnace and just above the throat is the charging arrangement consisting usually of two bells, a large one below and a smaller one above, each fitting in a hopper and so arranged that only one can be lowered at a time to prevent the escape of gas. Various devices are used to distribute the ore evenly in the furnace. This distribution is an important factor in prolonging the life of the lining of the furnace, the time required for melting and the quality of the iron.

The materials used in making pig iron are iron ore, fuel and flux. The ore is kept in huge piles in a yard and is handled by a large traveling crane. The cranes load the ore into bins from which it is run into small hopperbottom cars called larries, which are supported on scales for weighing. These larries dump the ore into buckets or skips which are hoisted to the top of the furnace up an inclined track and dumped automatically on the upper bell or into a hopper. The flux is handled in the same way while the coke is measured in cubic feet, the contents of a skip representing a definite weight. This method is known as skip charging. The old way was to weigh the materials in wheelbarrows which were raised to the top of the furnace by an elevator and dumped around the bell by hand. One complete charge of ore,coke and flux is called a round.

Gas generated is taken off at the top of the furnace through one or more openings connected with a large pipe called the downcomer pipe, which leads to a large chamber on the ground, known as the dust catcher. In this device most of the dust which consists of a mixture of fine ore and coke together with a little flux is deposited. Here the direction of the gas is also changed. As a rule no water is employed but if part of the gas is to be used in gas engines, it must be purified by being lead through a chamber, where it is sprayed with water and passed over moistened bricks. The heating value of the gas, however, is low—85 to 100 B. t. u. Only about one-third of the gas is necessary to heat the blast and the rest may be used for power.

The top of the furnace often is provided with a number of counterweighted doors, called explosion doors, which open automatically to relieve any excessive gas pressure. In some cases, however, these doors are omitted and the top so designed as to have sufficient strength to withstand an explosion. A door which can be opened from the ground to relieve gas pressure is called a bleeder. In early practice the gas was allowed to escape into the air and burn, being led away from the charging hole by a chimney in order to protect the workmen at the top of the furnace.

The air blast used in blast furnace operation is heated by passing through stoves. These stoves are cylindrical in form, up to 100 feet high and consist of a steel or iron shell lined with fire bricks which form a number of flues or passages. Depending upon the number and the arrangement of the flues, they are known as two-pass, three-pass stoves, etc. They are regenerative in principle, gas being introduced and burned at the bottom, the products of combustion going out at the top. When a stove is hot, the blast is forced through in the opposite direction, the two operations occurring alternately. A large furnace generally has four stoves, three of which are being heated by gas at one time, while the fourth is heating the blast.

Another operation on the blast is drying it. This is accomplished by passing it over pipes in which brine at a temperature of about 32 degrees Fahr. is circulating, the moisture being deposited on the pipes as ice. The heating and drying of the blast are two of the most notable strides in advancement in blast furnace practice.

The hot blast increases the temperature near tuyeres and localizes the combustion, thereby requiring less air. The upper part of the furnace is cooler and the gases carry off less escaping heat, thus cutting down fuel consumption and increasing the yield of the furnace. Drying of the blast prevents 100 to 500 gallons of water from entering the furnace per hour and results in considerable increase in efficiency and fuel economy.

The blast is driven into the furnace by immense blowing engines similar to air compressors but much larger. These engines run up as high as 2500 horsepower each and are capable of compressing 50,000 to 65,000 cubic feet of air per minute at a pressure of 15 to 30 pounds per square inch. It requires about 4 to 5 tons, approximately 100,000 cubic feet, of air per ton of iron produced. Alternate layers of fuel, flux and ore fill the furnace down to the top of the smelting zone, the location of which depends upon the volume and pressure of the blast, size of furnace, etc. The fusion or smelting zone extends usually, however, from the level of the tuyeres to a few feet above them or about to the top of the bosh. It takes about 15 hours for the material to descend from the top of the furnace to the bosh. During this descent the material is held up by the uprushing column of hot gases, the friction of the load on the walls and by the loose column of coke which extends through the smelting zone to the bottom of the furnace. Coke alone of all the material resists melting in the intense heat of the zone.

The blast entering the furnace through the tuyeres consists of 23 per cent by weight of oxygen and 77 per cent by weight of nitrogen. The nitrogen is chemically inactive and does nothing except to absorb heat in the smelting zone and lose it at higher levels. The oxygen attacks all the coke in the smelting zone and some of it below the tuyeres to produce a great volume of carbon monoxide gas (CO) and a temperature of 3000

degrees Fahr. or more. The hot CO and nitrogen pass up between the particles of solid matter, to which they give up the greater part of their heat although the CO also reacts chemically with the iron ore.

At the top of the furnace the following reactions take place between the ore and the gases:

(1) $2Fe_2O_3+8CO=7CO_2+4Fe+C$

(2) $2Fe_2O_3+CO=2FeC+Fe_2O_3+CO_2$

This action continues with increasing rapidity as the material becomes hotter. The carbon formed in the first reaction deposits like lampblack on the ore. The carbon dioxide gas (CO_2) opposes those two reactions as follows:

(3) $Fe+CO_2=FeO+CO$

(4) $C+CO_2=2CO$

The third reaction begins at 575 degrees Fahr. which is at a point only three or four feet below the top level of the stock and the fourth begins at 1000 degrees Fahr., or 20 feet below the stock line. The latter is so rapid that the deposition of carbon ceases at 1100 degrees Fahr. All the way down the ore is constantly losing oxygen to the gases. Above 1100 degrees Fahr. FeO is stable but practically all of the $Fe2O_3$ has been reduced.

(5) $3Fe_2O_3+CO=2Fe_3O_4+CO_2$

(6) $Fe_3O_4+CO=3FeO+CO_2$

The deposited carbon has also helped to reduce the oxide of iron.

(7) $Fe_2O_3+3C=2Fe+3CO$

At 1300 degrees Fahr. the solid carbon begins to reduce the resistant FeO.

(8) $FeO+C=Fe+CO$

Practically all the iron is reduced to a spongy metallic form by the time the temperature of 1475 degrees Fahr. is reached. This is about 45 feet from the top stock line and less than 30 feet above the tuyeres. At this heat the flux is beginning to be decomposed by the heat, and only the oxide CaO comes to the smelting zone. The foregoing equations show the general reactions that occur.

In the first 15 to 20 feet of stock the oxides of iron $Fe_2O_3+Fe_3O_4$ are converted to FeO by CO gas forming CO_2 gas, which is in turn partly reduced by metallic iron and carbon, as shown by reactions 1, 3 and 4.

From 20 to 35 feet below the stock line is the region of FeO being converted into metallic iron sponge by the carbon and CO, and the flux losing its CO_2. From 35 feet down to the smelting one is the region of metallic iron. The spongy iron absorbs carbon which lowers its melting point.

Upon reaching the smelting zone the iron melts and trickles down over the column of coke from which it completes its saturation with carbon. Here the flux unites with the coke ash and the impurities in the iron ore to form a fusible slag which also trickles down and collects in the hearth.

During this transit the different impurities are reduced by the carbon and the extent of this reduction determines the characteristics of the pig iron, since all the reduced elements are dissolved by the metal and the oxides by the slag. Only one exception is noted. Iron dissolves its own sulphide, FeS, and also manganese sulphide, MnS, to a lesser extent.

A large amount of silicon always is present in the coke ash and some of it is reduced.

(A) $SiO_2+2C=Si+2CO$

The extent of this reaction will depend on the length of time the iron requires to drop through the smelting zone, the amount of carbon tending to reduce it and the ability of the slag to take up silicon. A slag with a high melting point will trickle down sluggishly through the smelting zone causing the iron to do the same and thus allowing it to absorb considerable silicon. A higher heat in the smelting zone promotes the reduction of silicon and this can be controlled by the blast. By increasing the amount of coke in the stock, more chance for the reduction of silicon is given through the presence of the excess reducing agents and the excess heat.

Sulphur enters the furnace with the fuel in the form of sulphide of iron (FeS) and iron pyrites (FeS_2). FeS will dissolve in the iron unless converted to sulphide of calcium CaS by the flux.

(9) $FeS+CaO+C=CaS+Fe+CO$.

The CaS passes into the slag.

From the above equation, it is evident that excess reducing agent and high temperature which give silicon products low sulphur. In all cases it is true that iron high in silicon probably will be low in sulphur. The iron that runs especially hot in the blast furnace is high silicon and low sulphur.

Manganese is reduced by the following equation:

(10) $MnO_2+2C=Mn+2CO$.

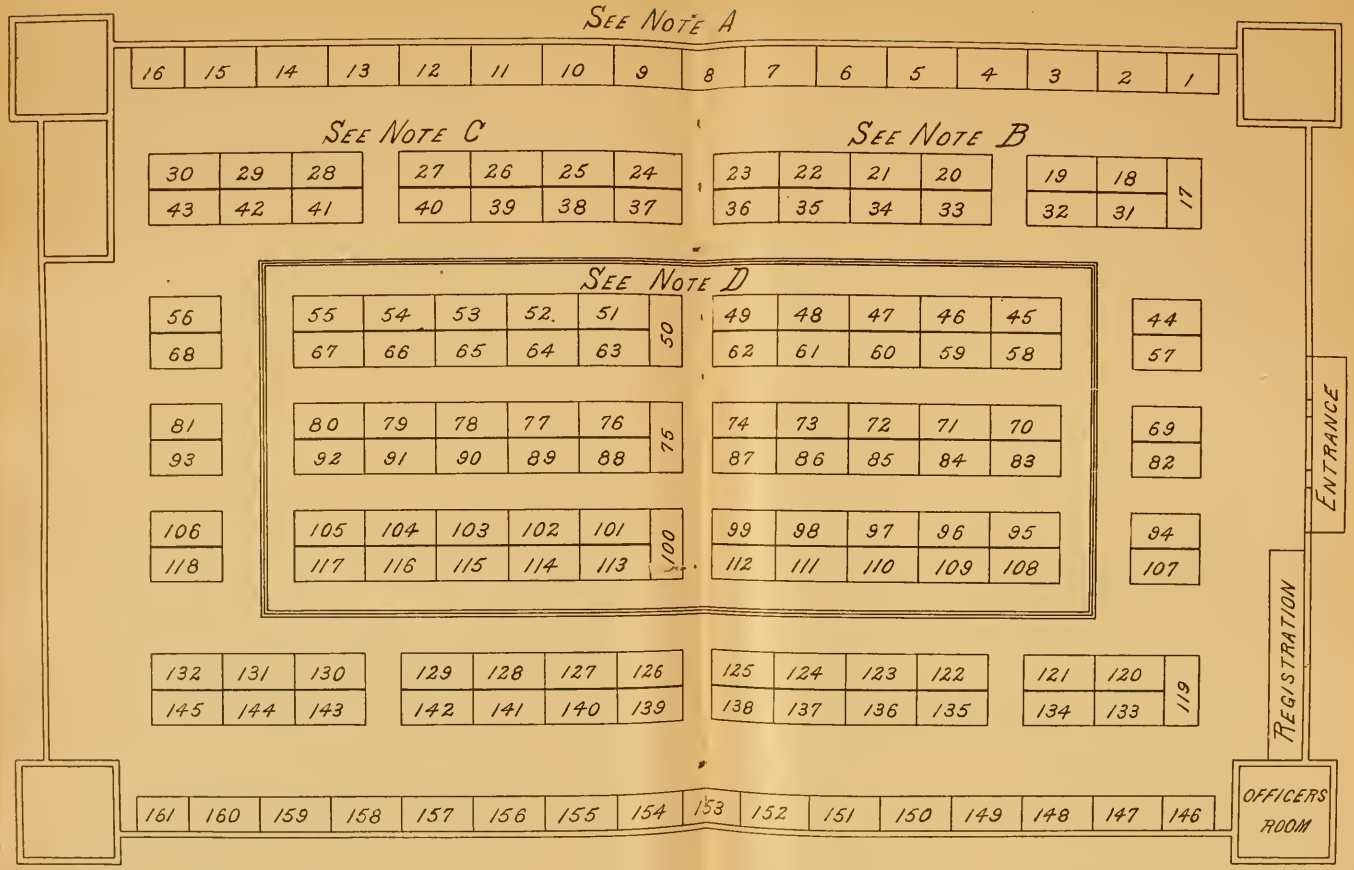
The amount of manganese in the iron depends mostly on the amount in the ore, but a highly acid slag will carry some of it away. Phosphorus in the iron is directly proportional to the amount in the ore.

The chemical influence of the blast furnace is a strongly reducing one, which is necessary to reduce the iron from the ore, to get rid of the sulphur and to saturate the iron with carbon. Processes have been tried in which the reducing influence was not as strong but the sulphur in that case is not removed, and this is one of the most objectionable of all the impurities liable to be contained in iron. The high carbon in the iron makes it melt at a lower heat than purer metal and thus makes it easier to work with and handle.

Slag being of lower specific gravity floats on the bath of molten iron, and accumulates until it nearly reaches the tuyeres. The cinder notch is then opened by withdrawing the iron plug and piercing the skull of chilled cinder with an iron bar, and the slag drawn off to the level of the notch. This is done three times between each tap, about five hours intervening between taps.

The slag flows down an iron runner and into an iron ladle car, which is drawn away by a locomotive and the slag poured out on the slag dump. The amount of slag varies from one-half to two tons per ton of iron, depending on the purity of the charge.

After the last removal of slag, the tap hole or iron notch is opened by drilling with a heavy pointed bar. Out of the notch flows 100 to 150 tons of liquid pig iron, which carries about 30 tons of slag with it. A skimmer is situated about 15 feet from the furnace and is an iron and refractory plate extending almost to the bottom of the iron runner. This deflects the slag into a runner of its own and it is carried away to the slag ladle. The heavier pig iron flows under the skimmer and is carried away to brick lined ladles mounted on cars if it is going to the steel works, or is poured into iron molds at the pig casting machine or is run into sand molds.



NOTE A Price $300 each. All booths 10 x 20 feet. Rental price of Nos. 1-16 inclusive includes artificial gas and air from 1½-pound compressor. Each has a 2-inch connection from a 4-inch line approximately in the center of the booth. For the exhibitor desiring to furnish his own compressor, alternating current at 220-volts, 3-phase, 60-cycle will be furnished in place of air. All connections are made by the exhibitor. No extra charge for gas, air or current.

NOTE B Price $300 each. All booths 10 x 20 feet. Rental price of Nos. 17-23 and 31-36 inclusive, includes power stubs in each. Current available is alternating, 220-volts, 3 phase, 60-cycle. All connections are made by the exhibitor. No extra charge for current.

NOTE C—Price $210 each. All booths 10 x 20 feet. Rental price of Nos. 24-30 and 37-43 inclusive includes stubs for lighting circuit at 110-volts, 3-phase, 60-cycle, alternating current, or power for small motors not over 1-horsepower, alternating current, 2-wire, 220-volts, single-phase, 60-cycle. All connections made by the exhibitor. No extra charge for current.

NOTE D—Price $200 each. All booths are 10 x 20 feet. All booths in the central section included with the rectangle surrounded by the triple line are in the "Sunken Garden," 20 inches below the level of the surrounding floor space. No current is available for exhibits.

Several types of pig molding machines are used but the most common consists of a long series of metallic pans, carried on an endless chain. The iron is poured through a spout into the molds as they travel under the ladle. The iron chills quickly in the molds and when at the end of the machine, the solid pig is dropped into a car as the chain passes over a drum. The pig iron is now in a convenient form for transporting or storing. The molds travel back to the spout upside down and are sprayed with lime on their way back to prevent the molten iron from sticking. This method of casting is easier on labor and gives cleaner pigs, no sand being stuck to them.

The sand method still is used at some places and some foundry men prefer sand cast metal since they can tell by the fracture what grade of casting it will make. In this method, the cast house extends in front of the furnace and its floor consists of silica sand, in which impressions are made to receive the liquid iron. The main runner extends down the middle of the floor and either side is used alternately for casting. From the main runner the iron flows into secondary runners forming sows which feed the molds of pigs. After cooling the pigs are broken from the sows and both are taken away.

The blast furnace is by no means a perfect machine and numerous difficulties are apt to arise. The chief of these is localized chilling of the semimolten charge. This most often happens in the upper part of the smelting zone where a pasty mass attaches itself to the walls of the furnace. This hinders the descent of the charge and also deflects the gases to other parts of the furnace. Such a scaffold as it is called is liable eventually to stop up the whole furnace. It is often removed by shutting off the blast and allowing it to fall of its own weight, but sometimes it is necessary to cut a hole in the furnace and burn it out with a blow pipe. With fine ores the scaffolds or hangings are most liable to occur and sometimes result in slips which cause explosions.

Sometimes material freezes over the mouths of the tuyeres and must be broken or burned away. Also the metal may freeze in the lower part of the hearth and make it impossible to open the iron tap hole. It is then necessary to drill a new hole. These difficulties all affect the quality of the product more or less.

The method of calculating the blast charge is interesting and important but we have not the time to go so far into detail. Electric furnaces for smelting ore to pig iron are being experimented upon extensively and there are a good many in operation in the Scandinavian countries.

FATIGUE BREAKDOWN IN AUTOMOBILE STEELS

By John Miller*

(A Paper Presented Before Buffalo Chapter)

One of the most troublesome problems with which the automobile engineer has to deal is that of localized stress. Some one has said that the Lord gave us shafts, but the Devil put the keyways in them. Keyways, splines and other sudden and sometimes unavoidable reductions of sections may cause, in service localized stress from which fatigue fractures often result. The crystal grains at these points are deformed or moved more than elsewhere and if the stresses are intermittent or repeated, the to and fro movement gradually loosens the crystals and a slow or creeping crack travels through the section. This action in soft steels has been studied by different investigators using the microscope. It formerly was thought that the metal crystallized but this is not so. The crystals are there to begin with and the repeated loads destroy their cohesion.

There are certain steels and heat treatments which are specially suitable for resisting certain degrees and kinds of repeated stresses. Localized stress can also be reduced by proper design, such as providing large fillets and absorbing shock by allowing flexure on the member or a connecting one.

The metallurigist and engineer working together are finding more efficient methods for the utilization of heat treated steels and aluminum alloys. The writer believes that in a few years, we will be building cars of one-half the present weight and carrying the same useful load with more all round comfort and convenience. In building lighter cars we will need to take more care with the heat treatment of the parts and we will require more information about their fatigue resisting properties.

The engineer's most valuable guide in designing parts, is past experience. Mathematical calculations help a great deal but it is sometimes difficult, if not impossible, to estimate correctly the stresses which many complicated sections on an automobile have to withstand.

The strength of heat treated steel depends on its resistance to permanent deformation and on its resistance to complete fracture, after deformation, has begun, or in simple terms, on its hardness and toughness. These two properties are very usefully indicated by two simple tests, the brinell test and the notched impact test.

The elastic limit is a figure used by engineers in their calculations and is a good test for resistance to permanent deformation, but it is difficult to determine accurately. The brinell test, when properly applied on heat treated steel, bears a close relation to the apparent elastic limit. From the reduction of area and elongation in the tensile test, we get some idea of the toughness of the steel, but the notched impact in combination with a brinell test is much more useful. It can detect brittleness, where the other tests do not. Sometimes, however, all the different physical, chemical, thermal and microscope tests are none too many.

Resistance to deformation or hardness, appears to be the most important property to have in steels for resisting fatigue breakdown in automobiles. Unfortunately, great hardness is usually associated with

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lack of toughness, a certain amount of which latter is necessary. In a very hard piece of steel not case hardened there sometimes appears to be very high internal stresses and if put into a machine in this condition, these stresses added to those received in operation might soon result in failure. To remedy this, we draw or temper the hardened steel. This reduces the internal stress and gives it toughness, but it also reduces the hardness. How much toughness we should have is the cause for argument. Really it requires careful judgement and an intimate knowledge of the work the piece is expected to do, the properties of steel and the methods to be used in manufacturing the piece.

The writer has been experimenting with a Stanton fatigue testing machine, as shown in Fig. 1, and the results, appear to confirm opinions, which he has formed from results obtained in actual practice.

This machine uses a test piece ½-inch in diameter, 6½ inches long. It has a groove of 0.05-inch, turned centrally between the two points of support. The latter are 4½ inches apart. The repeated stress is obtained by a hammer weighing 5½ pounds. This is raised to a selected height and allowed to fall on the test piece, striking it in the middle, first on one side, then the test piece is rotated half a revolution and it gets a blow on the opposite side. This gives an alternating and localized stress at the bottom of the groove which has a small radius. The rate is 100 blows per minute and when the specimen breaks, an automatic switch stops the machine. A counter registers the number of blows. The fracture looks very similar to the fatigue fractures seen on a broken steering knuckle spindle. On the same material, fairly uniform results are obtained. The machine is quite useful for comparing the fatigue resisting properties of different metals and heat treatments.

The correct method for making fatigue tests is to take the same material and run three or four tests using a different intensity of stress in each case.

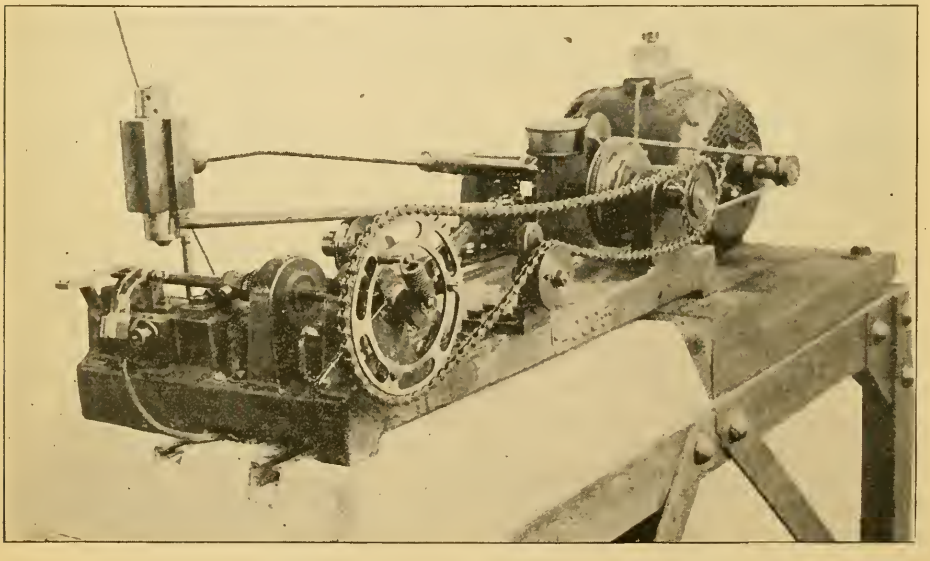

Fig. 1—A View of the Stanton Fatigue Testing Machine

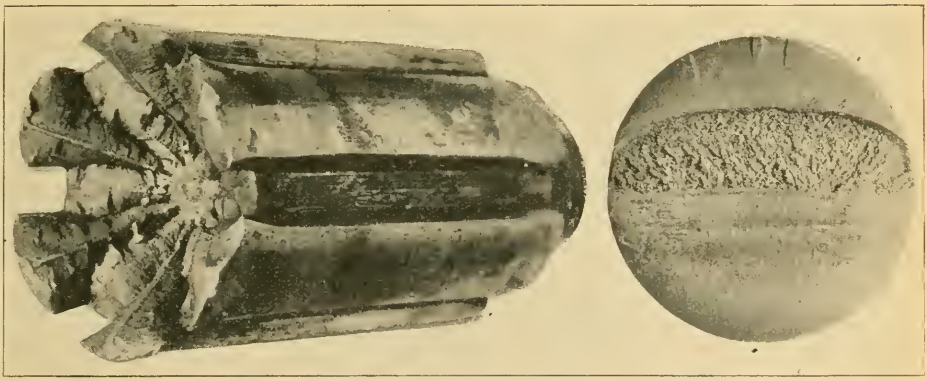

Fig. 2 (At the left) Shows the Fatigue Fracture of a Splined Steel Shaft. Fig. 3 (At the right) Shows a Photograph of the Fatigue Fracture of a Steel Steering Knuckle

If a curve is plotted, stress against number of blows, the behavior can be shown clearly. In the Stanton machine, a different stress can be obtained by using any fall up to 3.5 inches. On steels, useful results are obtained in a short time, from 10 minutes, to 1 or 2 hours according to strength, by using a 2-inch fall.

A piece of soft untreated steel, as example 0.20 per cent carbon screw stock, ½-inch diameter, will break after about 1500 blows. If quenched in water from 1650 degrees Fahr., it will stand 3000 blows. A piece of 3 per cent nickel steel, 0,20 per cent carbon, ½-inch diameter cold rolled, brinell 207, withstood 3500 blows. A piece from the same bar was quenched from 1500 degrees Fahr., in oil, brinell tested 387 and withstood 11,328 blows before it broke.

It is unusual for heat treated alloy steel to withstand much more than 10,000 blows with the 2-inch fall. Most of the different alloy steels properly heat treated in different sizes from ½ to 2½ inches thickness with a brinell hardness of from 248 to 302 give Stanton tests from 6000 to 8000. When treated to 302-418 brinell, we may get from 8000 to 12,000.

As the hardness increases above about 400 brinell or about 65 scleroscope, the steel does not stand up so well under the same height of blow. Most alloy steels, with 0.30-0.50 per cent carbon, hardened to about 500 brinell, last only about 2000 blows. Plain high carbon steel with this degree of hardness lasts about 500 blows. A steel with 0.20 per cent carbon and 3.5 per cent nickel quenched in oil from 1500 degrees Fahr. and not drawn, brinell 418 withstood 11,000 blows. Using much lighter blows, 0.5-1 inches the harder steels would not show such apparently poor results.

There are some parts of cars and trucks which under severe conditions receive shocks resulting in localized stress which must be about as much as the localized stress of the Stanton test using a 1-inch blow or even a 2-inch blow. With a 1-inch blow, the stress seems to be about 70,000 pounds and with a 2-inch blow, about 90,000 pounds per square inch. It is almost impossible to calculate it correctly.

It is usual in the best automobile practice to use for the more highly stressed parts, alloy steels, nickel chrome or chrome vanadium according to individual preference, quenched and drawn before machining, to a brinell hardness of about 248-302. This is as hard as can be machined economically and it gives a good combination of hardness and toughness. Full floating live axle shafts generally have a longer life under hard use if treated after machining to give 302-418 brinell. For this hardness on large sections, a fine grade of steel is necessary. If the steel is of poor manufacture, or not heat treated properly, the internal pressures arising from quenching may, combined with service stresses, cause failure.

Springs are treated to give 375-444 brinell. Oil tempered transmission gears which must have great hardness to prevent surface fatigue and deformation, are treated to give 444-532 brinell.

The writer has examined a great many parts of cars and trucks which have seen hard use and has noted that the ones which have given good service, have usually been hard with a good toughness. Parts which have failed by fatigue and where the design is not at fault usually show up soft under the brinell and sometimes they are brittle. Occasionally there are flaws in the material. One thing which has impressed him is that case hardened parts seldom fail by fatigue. When they do, it is usually because the hardness or depth of the case is not great enough. Sometimes places are left soft in order that they can be straightened or machined. Slow fracture can then occur comparatively easily. The writer has found that case hardening often will greatly increase the life of a highly stressed part when all other treatments fail. On rivet sets for pneumatic hammers, nickel and nickel chrome steel case hardened all over has given good results. On a large steam engine, a mild steel 1-inch bolt locking the connecting rod bearing would fail after running a few days. A nickel chrome steel heat treated to 364 brinell lasted about a month. A bolt made of nickel steel and case hardened lasted 2 years. Case hardening gives a high elastic limit where most useful to the outer fibres or crystals and toughness to the core.

Experiments on the Stanton machine indicate that 3.5 per cent nickel steel with 0.20 per cent carbon, carbonized 0.04-0.06 inch and quenched in oil from a temperature high enough to break up the cementite network and not drawn, gives results difficult to surpass with any other steel or treatment, which has been tried. For instance, a 3.5 per cent nickel, 0.20 per cent carbon steel with a 0.06-inch case, quenched from 1500 degrees Fahr. in oil, withstood 30,000 blows using a 2-inch fall. Using a 1-inch fall, other conditions the same, it withstood 300,000 blows. The best result obtained with steels not case hardened with a 1-inch fall was only about 50,000 blows. The life decreases when the depth of case is less than about 0.035-inch. It also depends on the hardness and toughness of the core this should be about 302-418. Drawing or tempering so that the case can be filed decreases the life. Using a double quench to refine the case also gave lower results.

The only reference to the fatigue resisting properties of case hardened steel which the writer has found is that in H. Brearley's excellent work on "The Case Hardening of Steel," which says, "One of the main objects of case hardening is to produce an article with a soft flexible core that

shall withstand sudden stresses or repeated vibrations, without developing cracks."

It would seem that very few engineers specify case hardening, unless they desire a very hard surface, which has to resist wear and they wish to avoid the brittleness associated with hardened high carbon steels. When they want a strong material they specify heat treated medium carbon alloy steel. There are several reasons for this. First, they may not know that case hardening has such fatigue resisting properties; second, the knowledge that the case hardening process, when not properly performed, sometimes results in reducing the strength by imparting brittleness; third, the risk of getting high carbon steel mixed with the proper low carbon stock; fourth, the treatment must be done after machining. Straightening a case hardened piece which has to withstand high stresses in use is not advisable; and fifth, case hardening costs more than plain heat treating. On the other hand, the value of the process and its success for highly stressed parts like the rear axle driving and differential gears, piston pins and vital parts like steering ball pins is widely recognized.

With improved methods of control we may see, in the future light car, case hardened steering knuckles, axle shafts, bolts and crankshafts case hardened all over. For parts like the front axle, case hardening would not seem suitable. A front axle should be fairly hard but also very tough and so that if bent in an accident, it could be straightened cold for slight bends, or after heating to about 1000 degrees Fahr. for bad bends. Other parts should be considered in a similar manner. Under loads beyond their capacity vital parts should be protected by allowing the shock to be absorbed in a flexible member or by straining one which is not so costly to replace or repair.

A PRACTICAL AID TO THE TREATMENT OF STEEL

By W. R. Ward*

(A Paper Presented by Title at the Philadelphia Convention)

Frequently one has a piece of steel from which a tool, jig, fixture or some part of a machine is to be made. The composition, grade or making of the steel may or may not be known by the one interested in it. If it is a case of a well known grade of steel—by well known, I mean well known to the particular user—previous experience with it has made him familiar with its characteristics. However, if he is not familiar with the steel he has about three alternatives to choose from in handling it: To follow instructions given by others who sell or have used the particular steel; to find out in the usual long way by making objects of it and trying them out in practice; or to resort to a simple test easily performed by a mechanic in a short time. This test I will describe later.

Steels that are used mainly for well known purposes, frequently possess remarkable physical qualities making them adaptable to other than the conventional uses for which the grade of steel is supposed to be suitable.

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What does it matter if the composition of the steel is not what it is supposed to be, if it will function successfully in the work to which it is applied. The proof of the pudding is the eating. The proof of the steel is in the service rendered by it irrespective of composition, name, grade, cost, etc.

The test alluded to is called the Metcalf test, and is known to most of you, but probably very little used. The ordinary fracture test of a piece of steel can hardly be called a Metcalf test. Many of those fracture tests are made throughout the steel business. They give only one physical condition of the grade of steel at its particular treatment. The fracture may or may not be the best one the steel could give under the proper treatment, thus it is not a true or fair test.

In making a test bar of steel whose physical properties are desired under a great range of treatments, two should be made as follows: A bar of the steel is forged 5/8 inch square by 36 inches long, nicked around in in the center while hot, and broken when cold. The bars are next properly annealed, and then nicked with a hack saw in inch multiples on opposite sides, and stamped from 1 to 18. The bars are sometimes nicked hot and not annealed.

The bars then are ready for treatment. There is an advantage in using a hot nicked bar in that it is cheaper to prepare, and gives the fracture of the forged steel in the first fracture.

The bars are first preheated by placing one end in an oven type furnace raising the temperature to about 1400 degrees Fahr., allowing one end to protrude through the door far enough not to get hotter than 400 to 500 degrees Fahr. The hot end of the bar after having been thoroughly soaked, is then placed about 3 inches in a high temperature furnace, such as a high speed steel treatment furnace, until the end begins to "sweat." It is then run back and forth in the furnace so as to give a gradual range of temperatures from the melting point to the black end. The object of not allowing more than about 3 inches of the bars at first to enter the high temperature is to allow the end pieces to soak, and not to overheat the following ones. These pieces, being out side, cool off a little but would readily obtain the desired tapered heat when moved backward and forward in the intense heat later.

One of the bars so treated is plunged into spring water at about 57 degrees Fahr., and another in cotton seed oil at room temperature, about 72 degrees Fahr. After cooling, the bars preferably should be sand blasted especially the oil quenched one, so as to rid them of any dirt, oil and scale. It is hard to get the oil out of the notches, and the sand blasting does this as well as any method. If there is any trace of oil, the fracture will be spoiled.

The bars are then held in a vice, and the inch pieces broken off one by one beginning with the melted end as they break more easily from that end. If a machinist's hammer of given weight always is used, a comparison of test bars can be readily made as far as their physical strength goes by the relative ease or difficulty met with in breaking the standard length pieces. Vice marks on them, also indicate the relative strength of the pieces.

The pieces should be kept clean, and put in some suitable case to be studied later after all the tests thus have been prepared.

The objection that the temperatures of each of these fractures are not known may be raised, but this is not necessary for all of the pieces. The

temperature of the best fracture which is just above the upper critical point is desired, and can be found with a little practice in a few trials by using double length pieces of the same stock treating them in the same quench, but at the assumed temperature of the desired fracture. If your temperature is above or below, it will show up in the fractures.

Since this is generally the only temperature desired for a given grade of the steel is forged 5/8 inch square by 36 inches long, nicked around in or other objects are to be made of the grade of steel on hand. File marks, scleroscope and brinell readings of one end of each piece may prove of interest and value.

It would be difficult to find words to describe properly the different fractures from one end of the bar to the other. Beginning at the melted end, the fractures are very coarse crystalline, and taper down to a very dense, fine grain, then change abruptly to a tough, fibrous fracture, changing not so pronouncedly at this end as at the highly heated end.

Useful tools have been made by the writer from supposedly inferior grades of open-hearth steel through the treatment aid given by this test. A good cold chisel that chipped tool steel successfully was made from a common steel rail.

PROGRESSIVE FAILURE OR FATIGUE OF METALS UNDER REPEATED STRESS

By H. F. Moore*

If a freight car axle is subjected to a heavy overload, the ductility of the steel of which it is made allows it to bend. The axle is distorted, but actual rupture of the metal will not take place. Consider now the case when the loaded freight car is running. For every revolution of the wheels there is on every longitudinal fiber of the axle a complete reversal from tension, pulling action, to compression, crushing action. If failure occurs after the car has run many thousand miles, the action is entirely different from the bending action under a single heavy overload. Almost without warning the car axle snaps short off, and the steel behaves as if it were a brittle material rather than a ductile material. Such sudden failure under repeated loading is said to be due to fatigue of metals, and occasionally occurs in shafting, automobile parts, airplane parts, wire ropes, band-saws, steam and gas engine parts, and other parts of rapidly moving machinery.

The apparent change in the nature of metal which fails under repeated stress gave rise to the theory that under repeated stress some profound change took place in the very nature of metal, changing ductile metal to brittle. This change was spoken of as crystallization and it was supposed that under repeated stress, metal changed its structure from fibrous to crystaline, and as evidence the sharp crystal appearance in the fracture under repeated stress was brought forward.

In the latter years of the last century, various metallurgists began to use the miscroscope as a means of studying the internal structure of metals, and their work, especially that of the English metallurgists Ewing, Rosen-

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A paper prepared under the auspices of the Engineering Foundation, the National Research Council, the General Electric Co., Schenectady, N. Y., and the University of Illinois Engineering Experiment Station, Champaign, Ill.

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hain, and Humfrey, showed that structure of metals is always crystalline either before or after repeated applications of load. They showed that the fracture under repeated stress was due to the spread of minute cracks, called by them slip lines, which extended completely through the crystals of the metal and which, spreading and uniting into larger cracks, acted similar to minute hacksaw cuts, gradually reducing the cross section of a machine part until it could no longer carry its load and suddenly snapped off, very much as a piece of iron suddenly falls off when cut almost in two by a power hacksaw.

The starting point for one of these minute slip lines may well be some point in the metal where a minute flaw exists, either in the shape of a flaw within the metal, or in the shape of a notch or sharp scratch on the surface. We think commonly that our mathematical formulas for figuring the strength of machine parts are exact, because they involve exact mathematical processes; as a matter of fact these formulas neglect thousands of minute actions which tend to destroy material. For example, they take no account of a cutting action where a shaft rests on the edge of a bearing. Under a single load, these minute actions are of no importance; their effect is so localized that no appreciable effect is produced on the deflection of a piece. If, however, the loading is repeated thousands or millions of times, then such a microscopic cutting action may start a crack, which under repeated stress will spread to causing final failure.

Any sharp discontinuity in metal, due either to a surface defect or to an internal flaw, greatly increases the stress in the metal over a microscopic area around it. This fact has been verified both by experiment and by mathematical analysis. As an example, it may be cited that the localized stress at the edge of a rivet hole may be as high as three times an average internal stress in the metal of a plate; the stress near the bottom of a sharp notch may be five or six times as high as a stress a few hundredths of an inch away from the notch. At the danger of wearisome repetition it seems worth while again to emphasize that these localized stresses are of negligible account for structural and machine parts subjected to few loadings, but may be of the greatest importance in the case of parts subjected to many thousands of loadings.

The problem of the designer and the metallurgist is to determine limiting conditions so that this progressive failure will not occur. The usual method is to make sure that no fiber in any part of a machine member is loaded beyond the elastic limit of the material by any load which will come upon it. The difficulty of applying this rule is twofold. In the first place, the determination of the true elastic limit of metal is a matter of a great deal of uncertainty. Delicate methods of measurement of stretch and careful methods of computation give an elastic limit lower, sometimes much lower than the value given by the ordinary commercial test. Some doubt exists as to whether actual material is perfectly elastic under any stress, no matter how small that stress is. Here again it should be noted that a slight inelastic action is of no account for a structure loaded but a few times. But under load repeated many thousands of times any damage due to slight inelastic action is cumulative and actually may cause final failure. In the second place it practically is impossible to figure all the small localized stresses in a machine member, especially in an irregular shaped machine member. Sharp shoulders or notches may cause localized stresses many times those which would be given by the ordinary formulas of mechanics.

This progressive spread of small cracks is offered as an explanation of the occasional failure of springs while under the action of light loads. At some time in its history a spring is subjected to a few heavy loads. These heavy loads start microscopic cracks and are not repeated often enough to cause them to spread far. However, these microscopic cracks are in themselves very sharp notches, and cause high localized stress under subsequent light loads with consequent spreading of the cracks and final failure. For a machine part subjected to repeated stress it may be necessary to know its history as well as the properties of the material in order to judge of its safety.

At the present time the most satisfactory method to determine the ability of material to resist repeated stress is to make acual tests of it under a great many repetitions. Over a year ago the joint investigation of fatigue of metals was organized by the National Research Council under the auspices of the Engineering Foundation, University of Illinois Experiment Station, and National Research Council and was given as its main problem, the study of the behavior of a number of common kinds of steel under repeated stress. Tests are carried for several specimens of each kind of steel to one hundred million complete reversals of stress.

The machine used for the greater part of the testing is, in principle, a car axle placed upside down. A circular specimen rotates in bearings and is driven by a motor; weights are hung on it at two symmetrical points along its length. The bearings used are all ball bearing so that friction is reduced to a minimum. The suspended weights set up bending in the specimen; compression along the top side of the specimen and tension along the bottom. When the specimen rotates 180 degrees, any given longitudinal fiber changes from compression to tension, a complete reversal of stress. A revolution counter gives the number of cycles of stress. The machine runs at 1500 revolutions per minute and operates day and night. A battery of 15 such machines now is in operation. In testing any kind of steel or other metal, tests are made on such a machine, using various weights. In this manner the number of reversals required to cause rupture is noted. It is found that there seems to be a fairly sharp limit of stress below which failure does not occur at one hundred million repetitions. Moreover, a curve plotted with stress as ordinates and numbers of repetitions for failure abscissas seems to be horizontal for this limiting stress. This stress is called the endurance limit of the metal, and is considered an index of the ability of the metal to resist repeated stress.

The quantitative statement of factors affecting the fatigue resisting strength of a metal cannot be given at this time, but certain qualitative indications may be noted. Those fatigue resisting strength of metal depends upon: (1) Its elastic strength; (2) its ductility; (3) probably the amount of initial stress left in it by heat treatment; and (4) its homogeneity of structure. Possibly still other factors enter. It is evident that high elastic strength would tend to increase the fatigue resisting qualities of a metal. The effect of ductility may be explained by the fact that at a small flaw in a piece of ductile material some stretching would be found with a consequent tendency to distribute the stress over more material than in the case of a brittle material. Initial stress would, of course, tend to start microflaws when a slight additional working stress was given. It might be noted that if an ordinary testing machine test is made of a piece of steel containing initial stress, the measurement of stretch would be taken over a considerable length of the

specimen and there would be a tendency for the positive and negative initial stresses present at different parts of the cross section to neutralize each other and thus to mask the first point of yielding of the specimen. This neutralizing tendency would not, however, prevent any initial stress from starting a crack when it was reinforced by a slight additional working stress. Inhomogeneity of a material is a source of weakness under repeated stress in that it permits the stresses to break down, first through the weaker constituents, and then through the stronger constituents because of the already started microflaws. Here again the ordinary tension test tends to give an averaging measurement of stretch, masking the first yielding of the weakest constituent.

Probably many cases of fatigue failure of machine parts are blamed on the material used, when they should have been blamed on the shape of the piece or on the surface finish. In conclusion, it is desired again to call attention to the great danger of starting microflaws at the root of sharp shoulders, notches, or rough tool marks on a piece. Good surface finish and generous fillets at shoulders are vitally necessary in a design of parts to be subjected to repeated stress.

TRUE ACTION OF CYANIDE IN CASE HARDENING STEEL

By G. R. Brophy* and S. B. Leiter*

(A Paper Presented at Philadelphia Convention)

Cyanide baths are in more or less general use throughout the industries as heating mediums for heat treating steel, but more particularly as a means for obtaining a very hard, superficial case for wearing parts. This hardness has been thought to be due to the absorption of carbon from the cyanogen radical, the nitrogen aiding the penetration of the carbon. Stoughton[1] says, "We may also use liquids containing carbon, such as potassium cyanide and potassium ferrocyanide. It would appear that the presence of nitrogen assists in the absorption of carbon by the steel, and for this reason the various animal and vegetable products mentioned are preferred to charcoal from purer materials. It is also common in some cases to introduce gases containing nitrogen such as ammonia into the receptacle where the cementation is being carried on."

As a result of the authors' studies, it has been found that the nitrogen of cyanogen is responsible for a greater part of the hardening than is the carbon.

Before going further with the discussion a brief review of the existing literature on nitrogen in steel will not be out of place.

For a bibliography of the important literature you are referred to a recent publication by G. F. Comstock and W. E. Ruder[2]. A few of the points pertaining to the present paper will be given.

A. H. Allen[3] states that nitrogen is present in all steels and gives a method for its determination. Nitrogen causes great brittleness in steel

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1. Stoughton, "Metallurgy of Iron and Steel."
2. G. F. Comstock and W. E. Ruder, "Chemical and Metallurgical Engineering," page 399.
3. A. H. Allen, Journal Iron and Steel Institute, No. 1, pages 181, 1880.

by being absorbed during heating to a red heat in an atmosphere of ammonia, and 0.5 per cent causes such brittleness that a bar dropped from 6 feet will break.[4]

According to G. I. Fowler[5], nitrogen exists in steel as Fe_2N and Braune states that possibly as Fe_5N_2.

Good steel was found by Harbord and Twynam[6] to contain from 0.006 to 0.017 per cent nitrogen, crucible steel containing considerably less.

H. Braune[7] found that nitrogen increased strength but decreased ductility; 0.045 per cent destroyed entirely the ductility of a 50 carbon steel; that nitrogen is absorbed in all metallurgical processes, especially under high temperature, basic slag and reducing conditions. He cites a case where nitrogen produced great brittleness in a hearth-iron made from pig iron coming from a blast furnace producing large quantities of cyanide.

J. H. Andrews[8] published the effects of nitrogen on the critical points and found that the points are suppressed by heating and cooling in ammonia and that in the presence of 0.030 per cent nitrogen the points are completely suppressed.

According to N. Tschischewcke[9], nitrogen below 0.05 per cent occurs in solid solution and cannot be distinguished metallographically; it then makes its appearance in annealed samples as needles until in the neighborhood of 0.20 per cent it appears as pearlitic patches. The brittle film of nitrogenized samples was found to contain 11 per cent of nitrogen.

Until recently it was impossible to distinguish between pearlite and the so-called pearlitic nitride patches, but while examining a sample of electrically welded steel, which had been etched with Stead's cupric chloride reagent, it was noticed that certain parts of the pearlitic patches were blackened, while others remained white.

The nitride needles were also blackened. This lead to the examination of many samples which had been treated with ammonia and others which there was reason to believe contained nitrogen in some form. Upon repeated applications of Stead's reagent, pearlite darkens but does not become black as does the nitride. Cementite remains white.

When cyanided steels were etched after this manner, it was found that cyanide patches could be distinguished readily from pearlite. This method of etching has been used in the microscopic study of the samples discussed in this paper.

Nitride in steel responds to heat treatment very much as does carbon[10] and the resulting structures may be mistaken easily for carbon steel structures. Annealing develops the needles and pearlitic patches as shown by Fig. 6. Quenching gives a martensitic structure, Fig. 3.

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4. H. N. Warren, Chemical News, Vol. 55, page 155.
5. G. I. Fowler, Chemical News, Vol. 68, page 152, 1894.
6. Harbord and Twyman, Journal Iron and Steel Institute, No. 2, page 161, 1896.
7. H. Braune, Stahl and Eisen, Vol. 25, page 1195; Review de Metallurgy, page 497, 1905; Jeinkontorets Annales, Vol. 59, page 636.
8. J. H. Andrews, Carnegie Scholarship Memoirs, Vol. 13, page 236, 1911.
9. N. Tschischewcke, Journal Iron and Steel Institute, No. 2, page 47, 1915.
10. W. E. Ruder, "The Effect of Nitrogen on Steel," Chemical and Metallurgical Engineering, page 399, 1920.

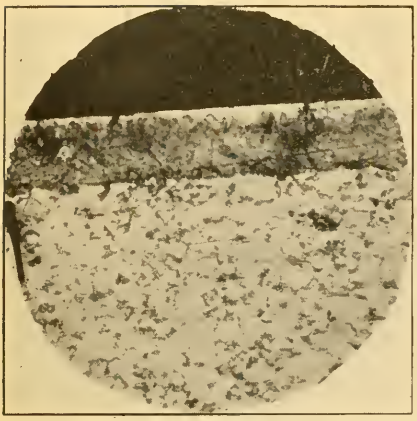

Fig. 1—Depth of Penetration x 100

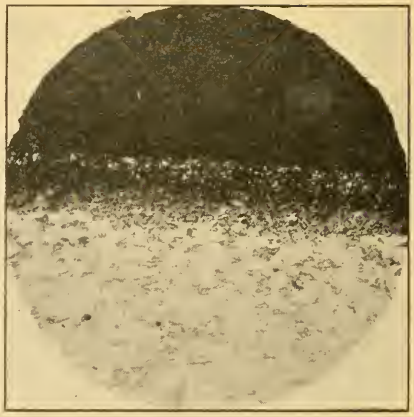

Fig. 2—Depth of Penetration x 100

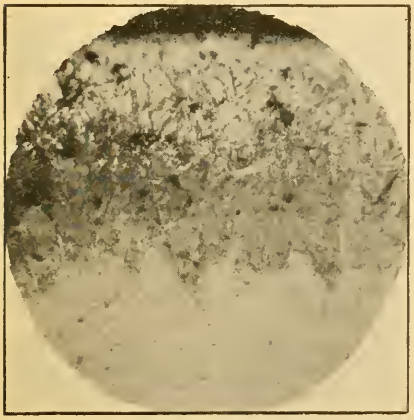

Fig. 3—Martensite x 250

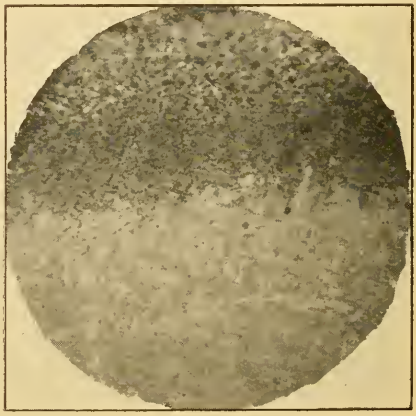

Fig. 4—Martensite x 250

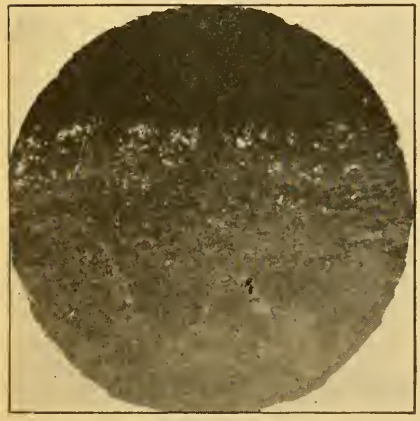

Fig. 5—Martensite x 250

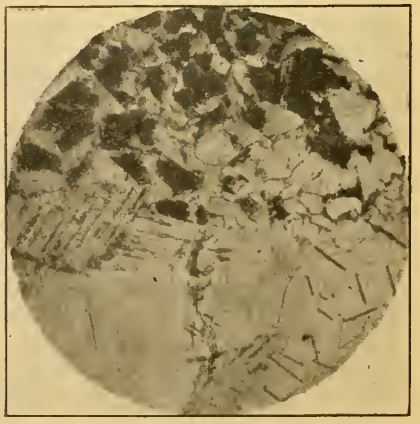

Fig. 6—Pearlite x 250

The case resulting from cyaniding and quenching from the baths is shown at low power in Figs. 1 and 2. Fig. 1 is low carbon steel heated 15 minutes in molten cyanide at 800 degrees Cent. and quenched. Fig. 2 is the same, but heated 30 minutes. The depth of penetration is the same in each case, but the concentration is greater and the diffusion better in Fig. 2.

Fig. 3 is iron, fired in hydrogen at 1000 degrees Cent. for 12 hours to burn out carbon, heated in cyanide 4 hours at 800 degrees cent. and quenched in water. The structure is martensitic.

Fig. 4 is the same as Fig. 3 but etched with Stead's reagent. Fig. 5 is the same iron heated one hour, quenched and etched with Stead's reagent. Fig. 6 is the same iron heated 4 times, quenched and then annealed at 900 degrees Cent., cooled slowly and etched with nitric acid. It shows nitride patches and needles. Fig. 7 is the same as Fig. 6 etched with Stead's reagent.

To prove the structures obtained in cyanided steels were nitrogen structures, a set of micrographs was kindly loaned by W. E. Ruder. These are of electrolytic iron, vacuum fused, nitrogenized by heating in an atmosphere of ammonia and variously heat treated.

Fig. 8 shows the characteristic nitride patches etched with nitric acid. These patches are easily mistaken for pearlite, although the laminations are not as fully developed. Fig. 9 shows the same patch etched with Stead's reagent, illustrating the differential action of Stead's reagent on nitride and carbon containing constitutents.

Fig. 10 is ammonia treated for 24 hours at 700 degrees Cent., reheated to 800 degrees Cent. and quenched in water. The needles have been retained in solid solution by quenching, but nitride appears at the grain boundaries somewhat resembling troostite in carbon steel.

Fig. 11 is electrolytic iron heated in ammonia for 24 hours at 700 degrees Cent., reheated to 700 degrees Cent. 15 minutes and quenched in water, reheated to 700 degrees Cent. and cooled slowly. Note the dark case resembling Figs. 1 and 2. The needles are characteristic of annealed nitride steels of lower nitrogen content and appear in the boundaries and slip planes of the grain. Ruder's work indicates that heating to at least 700 degrees Cent. is necessary to cause the appearance of needles.

Fig. 12 is the same material but quenched from 950 degrees Cent., followed by annealing at 950 degrees Cent. The grain has been considerably refined and the nitrogen of the case diffused greatly.

Analyses of the cases of steel rods originally containing 0.04 per cent carbon show an average of 0.33 per cent carbon after 4 hours heating in cyanide. This carbon content is not sufficient to cause the hardness attained by cyanided steel. A quenched 30 carbon is readily filed and has a Brinell hardness of about 207. A cyanided wire heated to dull redness and cooled slowly is still so hard that it is filed with difficulty, differing in this respect from a carbon steel. Therefore, it would seem that nitrogen is the hardening agent.

The brittleness imparted by nitrogen is illustrated by bend testing annealed cyanide wires after removing the case. The untreated material withstands 24 right-angle bends, while the annealed cyanided wires

stand but two bends before they snap. The reason for this is seen by examining Fig. 13, which shows the structure at the center of an annealed cyanided rod 3/16 inch in diameter.

The effect of cyanide and nitrogen on higher carbon steel has not been definitely determined as yet. However, it is known that nitrogen embrittles to a greater extent the higher carbon steels, even though refining the grain. A 50 carbon steel was heated 4 hours in cyanide, quenched and annealed at 850 degrees Cent. and cooled slowly. The case was very fine grained, showing a few needles on the interior. Evidently carbon retards the penetration of nitrogen.

Conclusions

Nitrogen has a greater effect in the cementation of steels by liquid carburizers than does the carbon.

Cyaniding greatly embrittles the steel treated and this effect is more or less permanent. Ordinary annealing does not restore ductility. Therefore parts resisting shock, even of small magnitude, should not be so treated for best results.

Solid organic matter, used often in carburizers, may have harmful effects.

Cyanide baths, as heating mediums in the best treatment of high grade steels and tools will cause brittleness which may decrease the life of the steel.

DISCUSSION OF MR. BROPHY'S AND MISS LEITER'S PAPER

MR. PATTERSON: I would like to ask Mr. Brophy if you can control the nitrogen penetration and keep it from making the core brittle in small sections.

MR. BROPHY: We have not tried to control it. I do not know that you can. Of course, the depth of penetration will depend upon the amount of ammonium or nitrogenous compounds present. We have not tried to control it any. On ¼-inch rods cyanided for twenty minutes we found nitrogen needles in the center; carburized in leather we also found needles in the center.

MR. PATTERSON: Is that true of cyanide hardening?

MR. BROPHY: Yes, we found needles present in the center in micrograph No. 13.

MR. ROCKWELL: I would like to ask Mr. Brophy about the physical properties of the iron nitride.

MR. BROPHY: It is very brittle. That is about all we know about it. Nitrogen raises the tensile strength more than the ductility. Perhaps Mr. Rouder can tell you more about that.

MR. ROUDER: Due to the difficulty of properly analyzing and getting a satisfactory analysis of nitrogen it is very difficult to say just what percentage has what affect on the steels. Generally speaking, however, the higher the carbon content the lower the quality of nitrogen necessary to make it very brittle. We have taken for example a very carbonaceous steel such as Mr. Brophy showed in the micrograph and nitrogenized it in ammonia, which is about the quickest way of getting nitrogen into the steel, and although as ductile as iron can be before being nitrogenized will, when we have this needle structure, be so brittle that you can break a ¼-inch rod

in your hand. According to the literature, I believe the limit for brittleness, as I remember it, given by some of the previous investigations, have shown that about 1-100 of one per cent of nitrogen in a 50 carbon steel, for instance, will make it too brittle for safety, and even 5-100 is necessary for making an ordinary mild steel brittle. But most of that work is rather indefinite. There has been considerable work done by several investigators on the affect of nitrogen on steel, but it has been my opinion that most of the metallurgists in general have looked upon that more as a theoretical consideration and have not given it a very serious thought for every-day work. This work done by Mr. Brophy shows that nitrogen is a thing to be dealt with in our every-day work and is itself practically, as far as he shows it, the real hardening agent in cyaniding processes.

MR. BROPHY: I have a note here from "Brown's Discussion of Nitrogen." It says, "Nitrogen increases the strength but decreases the ductility .° Nitrogen is absorbed in all metallurgical processes."

MR. McCLEARY: I would like to ask Mr. Brophy if there is a secession of the penetration after a given length of time in the cyanide bath. Your statement was that the needles occurred in the center of the piece and yet your general understanding in cyaniding has been that the hardening effect was not close to the center, in fact, confined to the extreme edge, possibly 0.005 or 0.010 of an inch.

MR. BROPHY: That is true; hardening is caused by nitride in the higher concentration of the needles. The concentration necessary to give the needle form of nitride will not give a hardening property.

MR. CLEARY: Have you noticed after a certain length of time in the cyanide bath, say a greater time than 15 minutes, that there was an apparent softening of the surface itself? In other words, what we have called a decarbonization?

MR. BROPHY: There is a loss of nitrogen on heating to high temperatures.

MR. McCLEARY: What I mean is this: that we have heretofore been familiar with using 10 to 15 minutes in the cyanide bath at about 1500 degrees and quenching in a cooling medium. A longer time than that has seemed to give us a decarbonized effect on the surface. The surface instead of being hard was apparently soft.

MR. BROPHY: Some of my samples shown were heated 4 hours in cyanide. In quenching they were still hard. There may have been some sort of an effect that we have not noticed. We are not interested immediately in the degree of hardness as much as we are in the effect, but the high concentration on the case itself, the depth, is not dependent upon the length of time heated.

MR. McCLEARY: Was there any copper plating on any of the pieces that were cyanided? I have noticed on copper plated pieces in solid carbonizers the same structure.

MR. BROPHY: No copper plating on any of those. Most of the samples were heated at a high temperature, at 1100 or 1200 degrees Cent.

MR. PATTERSON: May I ask what the affect of small quantities of nickel in the steel would be? We find that one-fourth of one per cent nickel in 10 to 14 carbon steel, heated 15 minutes in cyanide at 1600 degrees and

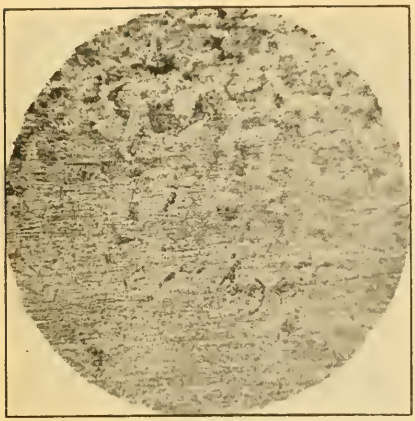

Fig. 7—Pearlite x 250

Fig. 8—Nitride Patches x 400

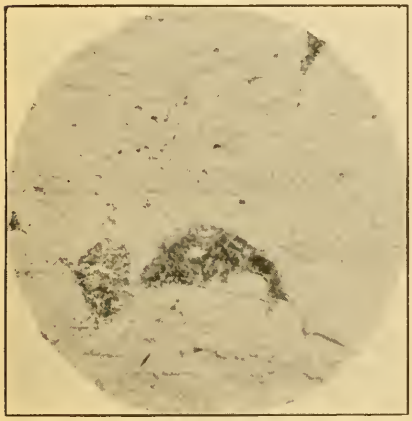

Fig. 9—Nitride Patches x 400

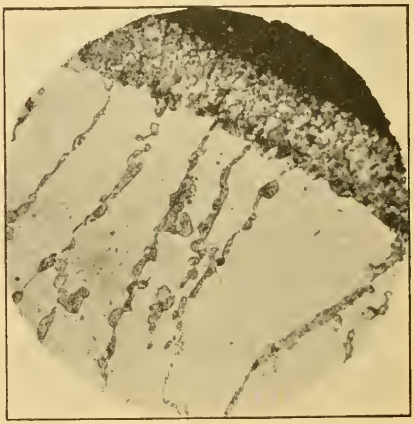

Fig. 10—Nitride Patches x 400

Fig. 11—Nitride Needles x 100

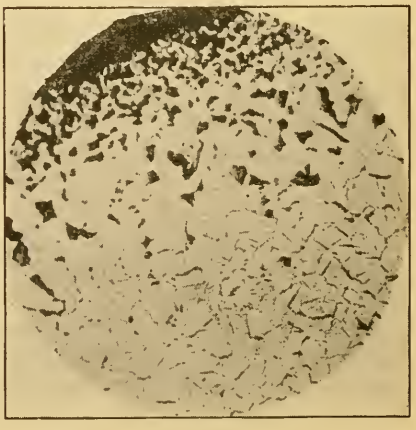

Fig. 12—Nitride Grain x 100

Fig. 13—Nitride Grain x 250

quenched in oil gives a case so hard it cannot be filed, and yet a shank on the tip which is about 0.10 inch in diameter can be bent 90 degrees before it will break. It seems to have a very tough core and we believe it is due to that nickel.

MR. BROPHY: Nickel may have some affect. A friend of mine carburized the specimens and we found no nitrogen present. We found nitrogen in almost all cases, but in this one particular case there was no nitrogen present. That may have been due to the fact it was an alloy steel. We have not investigated thoroughly an alloy steel.

MR. PATTERSON: What nickel content?

MR. BROPHY: That I do not know.

DR. HARTZELL: I would like to ask the vanadium content, if it contained vanadium, or what affect vanadium would have, if any, in checking the hydrogen penetration in a molten mass.

MR. BROPHY: I do not believe it would check the penetration. The vanadium would have an affinity for it in the solid steel. I will say off-hand that vanadium, if anything, would take it up faster.

DR. HARTZELL: Would it actually have any affect at all on the nitrogen in the cold steel?

MR. BROPHY: The vanadium nitride in the needle is similar to a so-called iron nitride.

MEMBER: I would like to ask if in the treatment of small watch parts you have found that in quenching them at about 1500 degrees after heating with cyanide, they became so brittle that you had to discard the cyanide method of hardening? We found that to be the case. From what I have learned in this paper it might be reasonable to suppose it is the nitrogen that has caused that to happen. Would you say that is a fact? The little pawl that causes the watch to tick and the little gears that cause the watch to run, in one of the lower priced watches, are all case hardened. They are made out of soft steel and case hardened. They work for years. When the manufacturers first started their case hardening they started it with cyanide, but they found they had so much trouble from breakage and the little teeth splitting off and little corners breaking on the pawl they had

to discard that method entirely. Are we to learn from this paper that that trouble has really been caused by nitrogen and not by carbon?

MR. BROPHY: I believe that is true.

MR. BURROUGHS: I would like to ask just what the concrete evidence is that the needle-like constituent is a high carbon? Would I understand that is a conclusion from your paper?

MR. BROPHY: No, we will call it nitride, because we have to call it something. It may be a cyanide, but we really do not know. There are evidences both ways. We tried some nitrogen determinations but they were not successful, and therefore when we met with no success there, we were led to believe it may not be a nitride.

THE APPLICATION OF FURNACE DOOR SCREENS

By Henry H. Wiegand*

(A Paper Presented by Title at Philadelphia Convention)

To discuss with steel treaters the terrific heat and glare that pours from a metallurgical furnace or oven, when the door is opened for charging or discharging, is needless. Everyone is familiar with its discomforts, but the majority has not been obliged to work close to these opened furnaces day in and day out as has the regular furnace attendant. It is for the alleviation of the lot of this man and thus to make his job more attractive and his output greater, that we will consider furnace screens.

When the door of a furnace on which the blast has been shut off is thrown open, the discomfort can be traced to three distinct sources; the convection heat, the radiant heat, and the glare.

The convection heat is due to the escaping of highly heated gases which quickly rise to the roof of the building, and are not so discomforting except to the man working close to the furnace. The radiant heat shoots out in straight lines and its intensity varies approximately inversely to the square of the distance from the source. This radiant heat is the main cause of the discomfort of furnace operators, which coupled with the glare that obeys the same laws, shoots out in a more or less horizontal shaft whose cross section is approximately that of the furnace opening.

Since man first began to employ an intensive fire, he has sought to protect himself from this heat and glare coming from an incandescent source. Although this endeavor has continued through thousands of years, yet it is only recently that marked progress has been made.

In the glass industry the earliest forms of protection were introduced. These consisted of sheets of iron which were suspended in front of the furnace; carried on the left arm like the shield of the Roman soldier, or born by a fellow workman, as the pavise of the archers of the Middle Ages. In the navy a stoker, to avoid punishment by the heat when cleaning fires, gets one of his fellows to hold a shovel between himself and the fire. All of these devices cut the efficiency of the operating force in half.

The immense growth of the steel industry with its fiercely heated furnaces, caused numberless efforts to be made to diminish the discomfort and danger suffered by the operators.

The most common form of screen used in this industry is the opaque sheet of iron which sometimes is fastened a short distance out from the

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furnace opening which it covers. The height of the bottom of the shield above the hearth is adjustable to suit the size of the work to be handled through the opening. This sheet iron screen is sometimes supported over head by chains or wires attached to either end. A hole sometimes is made in these screens for observation and for the introduction of tools. The swinging screen is said to have been used with advantage in some plants to facilitate the unloading into quenching tanks.

These opaque screens are useful on furnaces whose charges must be manipulated while under blast but their usefullness is seriously diminished if they become red hot; as the hot plate merely relays the heat originating in the furnace.

The life of screens subject to live flame is not great, as these soon warp and burn out. Sometimes liners are placed on the side of the screen to ward off the fire are to prevent the flames from impinging on the outside plate and also to minimize renewals. These screens usually are made of boiler plate. Perhaps if made of cast iron, they would not so readily take on a permanent warp, but they would be more liable to breakage unless made heavy.

Recognizing the necessity for viewing the interior of the furnaces, as well as protecting the men, a close mesh wire grating similar to a fly screen though made of very much heavier material, was substituted for the opaque sheet. This afforded visibility until the interstices became clogged with dirt and scale but penetrability was absent.

To prevent relaying of the heat brought directly to this type of screen, continuous streams of water frequently have been made to play over the screen which sometimes is tilted to insure better contact of the water with the heated surface. Such screens are usually made of boiler steel and unless supplied with the stream of water, warp and become more or less corrugated. The water then flows only in the valleys, and the ridges become sources of radiation. Another variety of water-cooled screens consists of a hollow box of thin sheet iron, which is fastened on the front of the furnace. A small stream of water is fed in at the bottom and passes out through an over flow pipe near the top. The top is open to avoid the danger of explosion through accumulated steam.

Screens cooled in this way add an appreciable burden to the factory overhead, as they consume an immense quantity of water and the presence of such a large chilled surface so close to the furnace demands more heat and consequent fuel. They also entail extra gears and fittings which require more or less skilled attention.

Another and serious drawback of the water-cooled screen is the increase in the moisture in the atmosphere around the furnaces due to the evaporation of the water. It is like turning a hot dry day into a hot humid one. As perspiration cannot evaporate freely in a wet atmosphere, the bodies of the men are not cooled in the way devised by nature and their efficiency is diminished.

None of the above forms of shields entirely cover the furnace opening, as being rigid and inflexible, a portion of the furnace opening must be left free for the entrance of the tools needed to handle the charge and of sufficient height to permit the charging and the discharging of the largest piece treated in the furnace. The main portion of the opening is covered by the screen, but the lower part continues to emit heat and glare.

An effort has been made to overcome the discomfort arising from this smaller opening by directing a sheet of air upward across the opening from a pipe perforated with a multitude of small holes. This helps to drive the convection heat upward behind the shield but has no effect on the radiant heat and glare. This adds another complication and additional cost to the overhead, for air under pressure is costly, besides it tends to cool the furnace itself.

A modification of this idea is contained in a furnace lately has been put on the market. This arrangement blows the sheet of air from above at an angle across the diminished opening onto the hearth, where this air mingles with the escaping convection heat that, by a special device preheats the air going to the furnace before it enters the furnace proper. This, like the sheet of air mentioned above does not affect the radiant heat and glare.

All the appliances heretofore mentioned are solid, opaque, cumbersome, and troublesome and while alleviating the trouble, do not serve the purpose fully. What was demanded was a door or shield which would permit a clear unhampered view of the interior of the furnace or oven; would not in any way interfere with the free manipulation of the tools required to handle the charge, yet a door that would keep the heat in and the cold air out. In other words, a door was required which should at the same time possess the qualities of opaqueness, transparency, flexibility and penetrability.

The nearest approach to this is the chain screen furnace door recently devised. The essential feature of this device is a sheet of chain composed of a multitude of freely hanging individual strands of small link steel chain suspended close together from a bar in a manner to form a continuous sheet or curtain of chain not unlike the familiar Japanese portiere. The single strands of chain give the penetrability and flexibility, the twisted metal composing the chain furnishes the opaqueness and the holes in the links of the chain produce the transparent effect. The closeness of the chain prevents free flow of the heat outwards or the cold inwards.

This curtain of chain hung before the uncovered opening to a furnace and resembling a coat of mail, effectively hinders the heat, glare, gases and sparks from leaving the furnace and the cold air from entering. These chain screens cover the entire opening down to the hearth, which the lower ends of the individual strands of chain just clear. Extended experiments made on furnace openings show, that while the radiant heat and glare come from all parts of the furnace opening, the convection heat flows out at the top and the cold air pours in at the bottom; so to prevent the chilling of the furnace it is necessary to keep closed the bottom as well as the upper part of the opening. Therefore, to save the heat and prevent the entrance of cold air, it is necessary to cover the whole opening, the bottom as well as the top, and this covering should lie close against the furnace front.

These chain screens are not to be considered as a substitute for the ordinary opaque door but merely as an auxiliary to be employed when the opaque door must be opened, or in those cases where the continuity of the operation compels the elimination of the ordinary opaque door. They do not keep all the heat in the furnace nor do they keep all the air out, but they materially decrease the losses. A great deal of the heat coming from the interior to the chains is reflected back and the cold air that does filter through the chains, keeps the chains relatively cool by robbing them of

their absorbed heat and enters the furnace preheated, thus saving heat that would otherwise be lost.

Experiments were made in order to obtain an idea of the effectiveness of this device in avoiding the losses arising from the opening of the opaque door. A thermometer was fixed on a standard at a point opposite the closed door and 10 inches distant therefrom, where it registered 110 degrees Fahr., as the temperature at this point when the ordinary door was closed. When this door was thrown open and the incandescent fire bed exposed, the thermometer rose to 400 degrees Fahr. On covering the furnace opening with the chain screen, the temperature at once dropped 265 degrees to 135 degrees Fahr., and the bare unprotected hand could be held anywhere in front of the screened opening without discomfort.

Photometric observations show the light and the glare of the bare fire are reduced about 85 per cent on covering the fire with the chain screen. The loosely hanging strands of light chain composing the chain screen with ease are parted and pressed aside by the tools or other objects projected into the furnace, only to fall together again and automatically close the opening when entrance has been effected.

Furnaces provided with these chain screens are charged, not only by thrusting individual pieces through the chains, but ore, fuel, coal and even shavings are thrown through the chains from a shovel. It is a common thing to see a boiler furnace being charged with fine bituminous coal through a chain screen without difficulty. The heat and glare are held back so effectively that the operator can work up to within five or six inches of the screen and can employ short length tongs and tools. This in itself is a great advantage as short tools are much handier and coupled with the cooler conditions at the furnace opening, enable the placing of the machines that are to operate on the heated metal close to the heating furnace, thus saving movement of men and metal, and shop space. Where the furnace charge is handled by means of tongs, the lower portion of each strand of chain often is replaced with light steel tubing. This prevents the chain catching in the crotch of the tongs. Where constant visibility is not needed, many screens are constructed with nearly the whole strand of tubing, only a short length of chain being placed at the top to insure flexibility and ready visibility. These tubular screens are impervious, yet retain the flexible and penetrable features.

Some electric furnaces whose contents caused a great evolution of fumes and heat have been inclosed with a circular screen of tubes nine feet long, each supported by a short length of chain from the edge of the hood that led to the stack. The furnace was thus encircled by a closed hood which could be freely entered or pierced at any point.

In factories where several furnaces demanding large screens are grouped together in a continuous line and not more than one is opened at a time, one or more screens mounted on an overhead track have been made to do duty for all.

Protecting shields, whatever their form have always greatly interested the safety engineer and have had his urgent advocacy, as he appreciates the ordeal undergone by the man whose duty holds him close to the furnace with its scorching heat. Many operators think only of the temporary discomfort, but effects follow which are slow in disclosing themselves.

Lately much attention has been directed to that insidious disease common among those whose occupation compels them to gaze at the glare emanating from incandescent materials, known to the medical fraternity as "Glass Blowers' Cataract." It is the general opinion that the universal employment of screens would avoid this affection.

The same applies to the eye trouble experienced by those who work around electric furnaces, and which is indicated by a violent inflammation of the eye ball and a painful sensation similar to sand in the eyes.

Many manufacturers, aside from the economical advantages to be thereby gained, actuated by truly humanitarian impulses have endeavored honestly to alleviate the undesirable conditions about their furnaces and their glowing products by the liberal use of screens, with the result that the health and eyesight of thousands now are safe-guarded and the operators stimulated to increased production.

ANNEALING AND HEAT TREATING MISCELLANEOUS STEEL CASTINGS

By Charles N. Ring*

(Presented by Title at Philadelphia Convention)

The process of annealing or heat treating steel castings to obtain correct and satisfactory results properly begins with the metal production department. In order to obtain uniform results from the heat treatment of steel castings for specified classes of work, it is necessary that the heat treater receive uniform material with which to work. Heat treatment will not give to steel properties which it does not contain, but it does bring out or make available properties that are inherent to the steel.

The province of heat treatment is to bring the steel to such a permanent or fixed physical condition that the inherent qualities of the steel can be utilized to the best advantage for the purpose intended. It therefore results as a corollary that, in order to secure the best results from the heat treatment of steel castings for specified purposes, it is essential that the heat treater be furnished with steel that contains in an inherent form the qualities that are necessary to obtain these results. The heat treating department and the metal production department should co-operate along these lines, and the production department strive to supply the heat treating department with metal conforming to specifications decided upon as the most desirable to obtain by heat treatment the results desired.

The first item to be considered by the steel treater is the chemical composition of the steel to be treated. The carbon content is naturally of the greatest importance, as indicating within approximate limits the temperature to which the steel must first be heated to reach the condition of solid solution and thus secure the finest grain structure of which the steel is capable. Manganese content is also important because of the bearing it has upon the strength of the steel and upon the ease or difficulty with which the steel will respond to a given heat treatment.

Phosphorus and sulphur content must also be taken into consideration because of the bearing these two elements have upon the strength and ductility of the finished product. Where a steel high in ductility is required,

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it is advisable to keep the phosphorus and sulphur content under the limit of 0.05 per cent. The effect of sulphur within the limits of 0.06 per cent is probably negligible in the finished product, but when over 0.05 per cent it has a tendency to produce red shortness in the metal, or, in other words, cause the metal to be weak when at or above a red heat. This weakness of the steel at temperatures above a red heat may cause the casting to crack because of the strains set up during the process of heating or cooling.

The effect of sulphur on steel when in the cold state is a much mooted question, and probably depends to some extent upon the condition in which the sulphur is contained within the steel. The tendency of modern opinion seems to be, that if sulphur is contained in the form of manganese sulphide, it has very little weakening effect upon steel in the cold state, but, if in the form of iron sulphide it has a greater tendency to weaken. Proper manganese content probably offsets any weakening effect of sulphur within reasonable limits. What these limits should be are at the present time under investigation by the American Society for Testing Materials, the bureau of standards, the railroads, and the steel manufacturers. When their report is submitted we shall probably know more about it than we do at the present time.

Carbon and manganese content are also of prime importance because of the direct bearing they have on the strength and hardness of the steel. There are numerous charts, formulas and data from which the proper content of these elements can be calculated to obtain a given strength or hardness. These charts, formulas, etc., will give approximate figures only, therefore to arrive at satisfactory results, experiments guided by this information must be made at individual plants under individual conditions.

Under conditions obtaining in a modern steel foundry, where production is a factor of prime importance, it would obviously be impossible to make experiments on each individual heat to demonstrate for which kind of work that steel is best fitted, or to see what heat treatment would secure the best results. The method to pursue is to group the different kinds of work in the shop into classes, according to the specifications demanded. The work in most foundries furnishing miscellaneous castings can be placed in from three to four classes. Study of these classes separately as to strength, hardness and ductility; figure the approximate chemical composition and the heat treatment required to obtain these results, and then, guided by the conclusions, experiment on each class separately until results are obtained from certain definite chemical limits and certain definite heat treatment that satisfactorily meets the requirements. Then formulate this chemical composition and this process of heat treatment that has given successful or satisfactory results into data for a standard practice for that given class of work. This standard practice should then be followed as long as it continues to give satisfactory results. This is where the cooperation between the heat treating department and the metal production department should begin to function.

When that steel conforming to certain chemical limitations is secured and subjected to certain definite heat treatment gives certain definite results within the required physical specifications of one of the classes of steel, inform the metal department that, when steel for this class of work is to be made, it should be within the chemical limits as determined by the

experiments. Furnish the metal department with a copy of the chemical limitations and the class to which they belong. The metal department should then strive to furnish the steel to conform to these limits.

Another matter worthy of serious consideration is the condition of the steel received for heat treatment, aside from the chemical composition. Steel, in order to show the maximum results from heat treatment, should be as thoroughly deoxidized during the process of manufacture as is practical in average commercial work. The presence of a large percentage of oxides or inclusions of slag and sulphides may have a very serious effect upon the size of the ferrite network and crystal structure of the steel. The metal department should bear this in mind and adopt methods to thoroughly deoxidize, cleanse and quiet the steel before casting.

Having received at the heat treating department the proper kind of material with which to work, the success of future operations rests entirely with the heat treater, and, in carrying out this operation, there are many items to be considered, the first of which is the furnace used for heating the castings. There are a number of different types of furnaces in common use that give satisfactory service and the type to choose is, of course, controlled by the local conditions, but whatever type is used, it is of prime importance that it be so constructed and operated that a uniform temperature can be maintained at all times in all parts of the heating chamber. This uniformity of temperature is as essential during the period of bringing up to the required temperature as it is after the required stage has been reached, otherwise there will be a loss of time and fuel in bringing that part of the furnace which lags behind up to equilibrium with the other part of the furnace. This will also cause part of the charge to be held at the maximum temperature for a longer period than the balance which heated up more rapidly and does not conduce to uniformity of results. If the furnace does not reach a stage of uniformity as to temperature in all parts of the heating chamber and maintain this uniformity at the temperature required, its use should be discontinued and it should be reconstructed to eliminate this defect.

The fuel used for generating the heat in the furnace can be either coal, gas, oil or electricity, all of which give satisfactory results if properly manipulated. Where coal, gas or oil is used, care must be taken that the castings are not subjected to the direct action of the flame, or they will be badly pitted and oxidized. Electrically heated furnaces are subject to closer control and maintain a uniform heat with minimum care, at the same time reducing surface oxidation to a very low figure.

In charging a heat, care should be taken to charge in one heat only castings of similar design or thickness of section. Castings of intricate design and small sections demand particular attention in charging, drawing and heating, and where charged with castings of simple design and with heavy sections, complicate the operation. If heavy castings and light castings are charged in the same heat, the light castings will come up to temperature considerably before the heavy ones, causing a loss of time and fuel by holding the furnace to temperature while the heavy ones are being heated uniformly through and up to temperature. This results in giving to the lighter castings a longer soaking than necessary and greatly increases the amount of surface oxidation on them. The heat treatment on the charge as a whole has been nonuniform and gives results in conformity.

The method of charging the castings into the furnace and withdrawing them from the furnace will also have a bearing on the uniformity of the product. The better method, where a continuous furnace is not in use, is to put the whole charge in at one time instead of piece at a time and withdraw in the same manner. Where the castings are charged into a hot furnace one at a time they will be brought up to temperature at different periods of time instead of approximately at the same time, thus giving to the different castings a different period of soaking instead of a like treatment. When withdrawing from the furnace one at a time for air cooling or other cooling treatment, nonuniform conditions are obtained by reason of the different temperatures at which the castings will be taken from the furnace.

The matter of temperature measurement is one of the most vital connected with the proper heat treatment of steel. After having determined the temperatures required, the utmost care should be taken to secure these temperatures with accuracy day after day. Good pyrometers with proper recording charts should be installed so that the furnace operator can depend on their readings to follow instructions as to temperatures, and also furnish a check to the man in charge as to how closely instructions are being carried out. When the operator knows that a graphic record is being made at all times on his furnace operations, he is much more apt to be diligent in following out instructions.

After proper pyrometer installation has been made, it should not be forgotten or allowed to run along without frequent checking to determine if it is reading and recording correctly. There are several different methods for calibrating the thermocouples and indicating on recording instruments, and this should be done at regular intervals. A neglected or inaccurate pyrometer installation is worse than none at all, as it gives a sense of false security leading to erratic results. Thermocouples should be attached to the furnace in such a manner that the different parts of the heating chamber can be under observation for irregularity as to temperature. One thermocouple permanently located at one point in the furnace does not show the uniformity of temperature maintained in the heating chamber.

In the treatment of castings requiring quenching, the same degree of care should be taken in the quenching operation to secure proper results as is necessary in the process of heating. The quenching medium used, of course, is controlled by the result desired. If extreme hardness is desired, water or brine can be used, or if steel of lesser hardness is wanted, oil, heavy, medium or light. Having selected the quenching medium to suit the purpose for which it is intended, the actual operation of quenching should be carried out with extreme care as to details. The quenching medium itself or castings quenched, should be vigorously agitated in order to secure the full chilling effect of the medium, otherwise the liquid quench immediately surrounding the casting would become heated and correspondingly lose its efficiency for extracting heat from the metal, thus giving a slower cooling than calculated. Nonagitation will also cause gas pockets to form around and about the casting itself and bring about a process of unequal cooling, tending to cause warping of the casting.

As stated before, the matter of composition of material to be treated, heat treatment to be given, such as first temperature, drawing temperature, quenching medium, temperature at which quenched and temperature at which taken from quenching medium, are all questions to be determined by the individual plant conditions, but working along well defined principles

and according to certain data ascertained by extensive experience of others entitled to speak with authority. All the items carefully considered and worked out to form a standard of practice will, nevertheless, be of no avail unless the human element is taken into consideration. By this is meant the man or men who are selected to carry out the operations decided upon. No system, method or business is better than the man running it. In other words, it is hardly possible to devise a method of operation that is fool proof, so that it is quite essential to have the one in actual charge of operations a man of ambition and energy, one who wants to learn, wants to follow instructions, and one on whose word absolute reliance can be had. This last human asset obtained, results in conformity with calculations can be secured, and any failures can be traced to their true cause and additional knowledge gained from the failures.

SCALING OR OXIDATION AND REDUCTION OF METALS IN FUEL-FIRED FURNACES

By O. Lellep*

(A Paper Prepared for the Philadelphia Convention)

"The furnace atmosphere in our furnaces can be kept oxidizing or reducing as you like," said the salesman of the furnace company to the engineer of a steel plant, who was buying a furnace equipment for heat treatment of steel. "Our furnaces practically do not scale steel heated in them as ordinary furnaces do, because we keep the fuel and air automatically in the same proportion. We synchronize their flow. Our regulation can be set once for all time for a neutral or even slightly reducing atmosphere."

The buyer was convinced of the automatic synchronizing or proportioning of the fuel and air for its burning and understood as the practical language explicitly means a neutral furnace atmosphere is an atmosphere which does not oxidize nor reduce, that a reducing atmosphere reduces or transforms the oxide or scale into metal. He also believed that as the manufacturer actually could make and maintain the flame neutral or reducing, there should be no scaling at all.

Under good expectations the bargain was concluded, the order placed and the furnace erected. The disappointment of the plant engineer was great when in actual operation at a comparatively high temperature and long heating the furnace showed scaling.

Who is to be blamed? The buyer thought that he had had something "put over" by the salesman and accused the latter. The salesman told him what he believed and what under favorable conditions was true, but as mostly done in business he did not tell the real truth. Furthermore, the reason for this disappointment to a great extent lies in the incompleteness or incorrectness of the practical language which often uses the terms reducing flame and oxidizing flame. To avoid confusion let us define accurately the conceptions concerned. According to Webster a flame is "A stream of burning gas or vapor, emitting light and heat." Thus, an expressed quality of a flame is the burning or the reaction between fuel and oxygen. If this reaction is accomplished there is no flame any more but only a stream of highly heated gas which still can emit heat and light. A poorly constructed primitive gas burner delivering unmixed streams of gas and air into the furnace and also an

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*Metallurgical engineer, Surface Combustion Co., New York.

oil burner actually give a flame according to Webster's dictionary. At these burners one can observe a pronounced zone of combustion. An efficient modern gas burner delivering theoretical homogeneous mixture and provided with means for localized quick combustion practically lacks phenomena of flame and is approaching flameless combustion especially at temperatures above 2000 degrees Fahr.. As a matter of fact, there is no such thing as generally reducing or generally oxidizing furnace atmosphere. A socalled reducing flame can be oxidizing and vice versa. To be clear let us consider some plain and simple experiments:

1. Suppose a small laboratory gas furnace is heated up to 1200 degrees Cent. with a correct homogeneous atmosphere containing a theoretical amount of air without excess gas and excess air—an atmosphere or flame which is called generally and also usually supposed to be neutral. Let us investigate its alleged neutrality. Into this furnace is placed a piece of magnesite brick with two cavities. One cavity contains a piece of steel needle and the other cavity a grain of cuprous oxide. After a while the steel is oxidized entirely and transformed into scale while the cuprous oxide is reduced into a rounded molten button of metal. Thus it is plain that a furnace atmosphere with a theoretical amount of air at 1200 degrees Cent. actually gives an atmosphere which reduces cuprous oxide into metal but under the same conditions oxidizes iron. Therefore, one can speak only of an oxidizing, reducing or neutral atmosphere for a certain metal or substance.

2. Let us consider any laboratory gas furnace which easily gives a high and controllable temperature as for instance the surface or flameless combustion furnace invented by Professors Lucky and Bone or a Meker furnace. Let the furnace atmosphere contain some small amount of excess oxygen, say 2 per cent and the furnace have a temperature of 1000 degrees Cent. Under these conditions a piece of metallic copper wire about 1-64 inches in diameter placed upon a piece of magnesite brick into this furnace will be oxidized entirely. Now let us raise the temperature of the furnace with a flame having the same amount of excess oxygen to 1700 degrees Cent. and place into the furnace upon a cupel a grain of cuprous oxide. After a while it will be reduced into metallic copper although the flame does not contain any reducing gas but contains a small amount of free oxygen. This experiment shows that besides the composition of the flame, a change in temperature can change the reducing or oxidizing qualities.

3. That a furnace atmosphere with a correct amount of air without free oxygen and without unburned gas, a socalled neutral flame, gives an oxidizing atmosphere for steel was shown by the first experiment. Let us heat our furnace in this third experiment with a rich flame containing unburned gas, for instance 7 per cent $CO + 2H$, which flame is generally but incorrectly called reducing. Let our heat treatment furnace have a temperature of 800 degrees Cent. and our steel needle be in the atmosphere of this flame. After an hour of heat treatment, one can observe a very thin layer of scale although the needle was plunged into oil in the furnace itself and thus any oxidization during the cooling period prevented. The thickness of metal destroyed by oxidation amounts to practically nothing—approximately 0.0005-inch—but undoubtedly the atmosphere, although it contained a considerable amount of excess gas, was oxidizing. If we were to try the effect of a flame with some small amount of excess gas at 1300 degrees Cent. we would notice that the

atmosphere remains oxidizing for steel. Thus a certain atmosphere can not only be oxidizing for steel and reducing for copper at the same time (1st experiment); but an atmosphere of a definite composition can be oxidizing for a metal at 1000 degrees Cent. and it can be reducing for this metal at 1700 degrees Cent. (2nd experiment). Further a furnace with a hearth open to fire gases remains more or less oxidizing or scaling for steel under all practical conditions in heat treatment furnaces (3rd experiment).

Thus it would appear that there exists an anarchy in the oxidizing and reducing conditions of an atmosphere for metals. That is only apparent for physical chemistry has given certain laws, which predict when a furnace will oxidize and when it will reduce. Whether a metal oxide will be reduced or a metal oxidized into scale depends only on the oxygen pressure and on the temperature around the substance. A metal oxide is reduced when the oxygen pressure of its decomposing oxide is higher than the oxygen pressure of the surrounding atmosphere, and a metal is oxidized when the oxygen pressure of its oxide under thermal dissociation is lower than the oxygen pressure in its surrounding atmosphere. It is comparatively easy to measure the temperature but much more difficult to measure the oxygen pressure at the thermal dissociation of metal oxides, which varies from several atmospheres for silver oxide to several thousandths of a millimeter mercury for iron. In the furnace atmosphere the partial pressure of oxygen must be considered. Partial pressure of oxygen in air is about 1/5 atmosphere or 760/5=152 millimeters of mercury. In a furnace gas resulting from burning fuel with 100 per cent excess air, it is half of this amount.

If fuel is burned with a theoretical amount of air in the furnace gases, the oxygen pressure approaches zero and measures in fractions of a millimeter of mercury, owing to some thermal dissociation of water vapor and carbon dioxide. In a rich furnace atmosphere with some excess fuel, incorrectly called a reducing flame, this oxygen pressure might measure in microns of mercury gage, but it exists and determines the all important conditions for reduction and oxidation of metals. Returning to the practical combustion gases and considering them from the viewpoint of reduction and oxidation, one can conceive that it does not pay to make the atmosphere in an open-flame fuel-fired furnace actually reducing for steel. But it could be made by some complicated means either by increasing the percentage of unburned gases and thus diminishing the amount of dissociated oxygen or by increasing the temperature.

In flames where fuel is burned not with air but with oxygen, for instance the oxycetylene flame, the conditions are much more flexible. In those flames the unnecessary ballast, atmospheric nitrogen which accompanies oxygen in four parts to one part is not present. Therefore, an oxygen flame gives a very high temperature so high that it is difficult to measure it. The oxygen pressure of dissociated oxides increases rapidly with temperature and therefore it is a comparatively easy matter to reduce actually with a very hot oxyacetylene flame iron oxides into metallic iron. The reduction of iron ore in a blast furnace also is due to a high temperature in presence of free carbon. An actually reducing condition for steel exists also in closed vessels as in carbonizing boxes in presence of free carbon, but ordinary steel heat treatment as hardening, forging and annealing furnaces remain slightly oxidizing or scaling

disregarding the unjustified and contradictory claims. A rich furnace atmosphere containing a large excess of fuel or falsely called reducing atmosphere remains actually slightly oxidizing for steel at these temperatures. Likewise the atmosphere of a muffle furnace, consisting of products of combustion or air is oxidizing for steel.

For the purpose of diminishing scaling effect it can be recommended:

1. To exclude free oxygen from furnace gases by using modern furnaces. There are on the market at present time well developed and very satisfactory automatic gas and air proportioning devices of different makes. For a gas furnace particularly, there is no excuse for free oxygen in furnace gases. The old assumption that some excess air was necessary for a complete and efficient combustion in gas furnaces is not true. A thorough mixing of air and gas before entering into the furnace helps much towards a complete and quick combustion. Localized combustion on baffle walls, impinging refractory beds and a combustion tunnel have the same effect.

2. To protect the steel from direct contact with the flame or to stay where the velocity of the furnace gases on the surface of steel is as low as possible.

3. In many forging and other heat treatment furnaces, the scaling is effected not so much in the furnace as outside of it during forging, pressing or moving from one place to another. This cause of scaling can be diminished by shortening the necessary time of exposure to a minimum.

The scaling of steel in furnaces is due to two causes: The presence of free oxygen in furnace gases; and the oxidization effect of carbon dioxide and water vapor. The first cause, free oxygen, can be eliminated entirely in a modern gas furnace by automatic gas and air proportioning devices. The second cause affects steel very slowing and for shorter heating operations below ½ hour practically is negligible.

The terms reducing or oxidizing atmosphere in furnaces or reducing or oxidizing flame are misleading or incongruous as there is no reducing or oxidizing condition in general but only relative reduction or oxidation of certain substances at a determined temperature and composition by the surrounding furnace atmosphere. It seems more practical, therefore, to state, instead of the misused reducing and oxidizing flame, a rich and lean flame; the first term defining a flame with more than the theoretical amount of fuel, the second term a flame with less than the theoretical amount of fuel.

News of the Chapters

NEW CHAPTER IN CHARLESTON

The first chapter of the American Society for Steel Treating to be organized by others than the National office was instituted in Charleston, W. Va., on the first of February. The application for the Charleston chapter was granted by the Board of Directors of the National Society late in December, upon the petition of some 17 interested men.

At the organization meeting of the chapter, Mr. H. Schagrin, chief chemist of the U. S. Naval Ordnance Plant, was elected chairman, and Mr. W. I. McInerney, foreman of heat treating at the armor plant of the U. S. Navy,

Harry Shagrin,
Chairman Charleston Chapter

was elected secretary-treasurer. The first stated meeting was held on Feb. 1st when 65 members were in attendance. A very interesting paper was presented by Mr. C. E. Margerum, metallurgist of the U. S. Navy Ordnance Plant, upon the subject of "Mechanism of Heat Treating." At the close of Mr. Margerum's paper, a very lively discussion was held, besides various matters of importance were also discussed.

The next meeting will be held March 1st when Mr. D. M. Giltinan foreman of heat treating of guns and shells will present a paper on "Pyrometry.'

The spirit and enthusiasm manifested by the officers and members portends a most successful career for the Charleston chapter.

Major F. H. Schoenfuss,
Vice Chairman, Charleston Chapter

W. I. McInerney,
Secretary-Treasurer, Charleston Chapter

THE PRESIDENT'S VISITS

Lt. Col. A. E. White, professor of engineering research, University of Michigan, and national president of the American Society for Steel Treating, completed his inspection of the Eastern chapters on Feb. 18. The chapters were visited in the order given:

Monday, Feb. 7—Boston
Tuesday, Feb. 8—New Haven
Wednesday, Feb. 9—Bridgeport
Thursday, Feb. 10—Hartford
Friday, Feb. 11—Springfield
Monday, Feb. 14—Providence
Tuesday, Feb. 15—New York
Wednesday, Feb. 16—Philadelphia
Thursday, Feb. 17—Baltimore
Friday, Feb. 18—Washington

At all of these chapters, special arrangements were made to entertain the national president, and a large turn out greeted him in every chapter. The stimulating effect of his visit was most pronounced, and he added many friends to his already large list of acquaintances.

CHICAGO CHAPTER

The Chicago chapter held its February meeting on Feb. 14 in the Lumbermen's Exchange building, at which time over 150 were present. Mr. Lowry, metallurgist for the Oliver Chilled Plow Works, South Bend, Ind., presented a very interesting paper on "Practical Malleable Anneal-

ing." Mr. Lowry has given many years study to the subject, and his paper proved particularly valuable to the producers and users of malleable castings. The second speaker of the evening was C. P. Berg, consulting industrial engineer of Chicago, whose paper on the "Relation of Heat Treatment to Factory Production" was very enlightening and particularly interesting to the executives of plants.

An interesting and well prepared letter sent out to the executives of plants by F. C. Lau, chairman of the Chicago chapter, was productive of excellent results in boosting attendance. Mr. Lau's letter follows:

January 25, 1921.

Dear Sir:

"We respectfully invite your attention to our organization which has for its purpose the advancement of the art of heat treating of metals and the placing of the industry on a more scientific basis. This fact has prompted our executive committee to try and co-operate with the heads of Manufacturing Plants as to the best procedure that will show results at the factory.

"INDUSTRIAL EXECUTIVES NIGHT, Monday, February 14th, at the Lumbermen's Association Club Rooms, 4th Floor, 11 South La Salle Street, will afford the opportunity. You will not be lonesome as over a hundred of Chicago's leading industrial executives have been invited. Dinner at 6:30, $1.50 per plate. Meeting starts at 7:30. If you cannot participate in the dinner, come at 7:30.

"Mr. Lowry, Metallurgist for the Oliver Chilled Plow Works, of South Bend, Ind., will address us on the subject of "Practical Malleable Annealing".

"After a limited discussion of this subject, Mr. C. P. Berg, Consulting Industrial Engineer of Chicago, will talk upon the "Relation of Heat Treatment to Factory Production".

"The merits of the AMERICAN SOCIETY FOR STEEL TREATING must be judged by results shown in quality and quantity of output in your heat treating departments.

"Your presence with some of your shop men that night will be well worth while. An apportunity to let men from the shop rub elbows with men from other shops who are encountering the same difficulties and overcoming them, will, we are sure, make them worth more to you.

"If you will kindly fill out the enclosed blank with the names of those you think are interested and whom you want to attend, we will be glad to make reservations for them.

Yours very truly,
F. C. LAU, Chairman."

PHILADELPHIA CHAPTER

About 100 members attended the meeting at the Engineers Club on Jan. 28. The principal paper of the evening was delivered by H. M. Brayton, research engineer of U. S. Ordnance Corp., on the subject of "Heat Treatment of Ordnance". At the close of Mr. Brayton's very interesting paper, Mr. G. Oertson, president of the Engineers Club gave some very interesting data on "Heat Treatment of Guns, by Midvale, for the U. S. Navy, in 1876." Mr. Bullens, consulting metallurgist, Royersford, Pa., and author of the text book "Steel and Its Heat Treatment", gave a short talk on the "Fundamentals of Heat Treatment with Special Reference to Critical Ranges".

The membership campaign has been especially successful and the total membership of the chapter at present is 226, and still growing. H. J. Huester received first prize of $10.00 for having secured the largest number of new members. A peculiar coincidence of this feature was that the number of new members he secured was 13. There was a triple tie for second prize, E. G. Gaughan, G. W. Tall, and G. P. Bible, each having 8 new members to their credit. Mr. Tall and Mr. Bible

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SELLING YOUR PRODUCT ON MERIT

Manufacturers more and more are realizing the importance of selling their goods on its merits or service performance. In these days of high competition and assortment of goods on the market, the average buyer demands complete information as to how the goods was made and how it was tested to show its ability to withstand the service he wishes to make of it. As a result, methods of manufacturing have been included in the selling points of salesmen.

Particularly is this true in the automotive field where motor car and truck builders have been quick to realize that proper heat treatment of car parts is of vital importance. Through the aid of metallurgical laboratories, manufacturers have passed on to its customers through its sales engineers, the proper hardening of gears to prevent breaking, the relieving of distortion and strain, annealing of parts to prevent warping, final refinement to give strength for the demands of service and many other details of manufacture.

Upon this information depends whether or not the buyer can operate a truck with profit. If manufacture has been slighted, or quality has been passed over for quantity, the cost of repairs will absorb profit of operation. The producer must and does appreciate this critical demand of the consumer and is continually perfecting his product to meet the demands for service.

METALLURGY CONTINUES IN ITS PROGRESS

At the present day with its high development of scientific processes and manufacturing methods, a belief too often exists that the future can not hold in store advances comparable with those of the past. Since man first learned to work with his hands in the early ages, he has continued in his advance through the centuries, devising new tools and new methods to simplify his struggle for existence. To be sure many of his discoveries came about by accident while he was engaged in his search for knowledge but each accomplishment was used as a means for further gain. This characteristic in man has shown itself in every generation and will continue to exist so long as civilization maintains its pace. The world will always expect to see this continuous advancement.

Without doubt the recent development of science has seemed somewhat obscure as a result of the attempt to invent methods for quantity production to meet the ever increasing demand for manufactured articles. Remarkable strides in this respect have been made during the past few

years, the great World War greatly accentuating this advance. Nevertheless, scientific discoveries in the modern arts continued to be made throughout this period.

A brief review of the progress of metallurgy, one of the earliest of arts, shows what progress has been made in the past to bring it to its present day status. But after all, man's experience, with this art and his lack of knowledge emphasize the great development which must come in the future before metallurgy may be classed as a finished science. Dr. Joseph W. Richards, in an article appearing elsewhere in this issue of TRANSACTIONS, points out in detail important development which must be made. Chief among the information needed are specific heats of all kinds of iron and steel, latent heat of fusion for steel, latent heat of vaporization of iron and steel, thermochemistry of metals, heat emissivity, electrical conductivity, and many other properties. Some of these problems already are under investigation by scientists and engineers and their results will at some later date be added to the present knowledge of iron and steel. Each problem solved marks the progress of metallurgy, this progress continuing as time goes on.

PHILADELPHIA CHAPTER HOLDS BIGGEST MEETING SINCE ITS ORGANIZATION

The largest meeting which the Philadelphia Chapter has had since its organization was held on Wednesday evening, Feb. 16, at the Engineers' Club, 1317 Spruce street. Members of the Chapter and their guests took dinner at the club at 6:30, the technical meeting following at 8:15.

Upon this occasion, the Chapter not only entertained and was addressed by Lt. Col. A. E. White, the national president of the Society,

JOHN J. CROWE
Chairman of the Philadelphia Chapter

H. C. KNERR
Chairman, Philadelphia Membership Committee

ARTHUR W. F. GREEN
Vice Chairman of the Philadelphia Chapter

ARTHUR L. COLLINS
Secretary-Treasurer, Philadelphia Chapter

who was making visits to a number of eastern chapters, but was fortunate in having as guests a number of prominent men, among whom were Dr. George K. Burgess, chief of the metallurgical division, Bureau of Standards, Washington; Dr. Joseph W. Richards, professor of metallurgy, Lehigh university, South Bethlehem, Pa.; Morris E. Leeds, president of Leeds & Northrup Co., Philadelphia; and Richard Spillane, business editor, *Public Ledger,* Philadelphia. Dr. John A. Mathews, president of the Crucible Steel Co. of America, Pittsburgh, had also planned to be present but being detained in Pittsburgh at the last moment, wired his regrets and sent a greeting to the chapter.

Each of the guests presented an address which will be found in detail on the following pages. President White, in a brief but highly interesting talk reviewed the growth of the Society and its activities, concluding with an optimism for the future expansion which time would bring. Following the presentation of the formal program, the meeting adjourned for a buffet luncheon, during which a round table discussion of the various papers was held.

An extensive and intensive membership campaign has been conducted by the Chapter recently with gratifying results. H. C. Knerr, metallurgist, Naval Aircraft Factory, United States Navy Yard, Philadelphia, as chairman of the membership committee, has been directing a well planned drive to round out the chapter roll. The membership now is well on its way toward the 300 mark. In the May issue of TRANSACTIONS, Mr. Knerr will report his methods and their success, with a view to assisting other chapters of the Society to swell the membership.

Officers of the Philadelphia Chapter are: John J. Crowe, chairman, metallurgist hull division, Philadelphia Navy Yard; Arthur W. F. Green, vice chairman, chief of laboratory, John Illingsworth Steel Co.; and Arthur L. Collins, secretary-treasurer, metallurgist, Ace Motor Corp.

NATIONAL PRESIDENT GREETS PHILADELPHIA CHAPTER

By Lt. Col. A. E. White*

We are to be congratulated tonight for as I looked over the table I found quite a number of men here whom I met in New York this morning at a meeting of American Mining and Metallurgical Engineers, and note these same men are so deeply interested in this Society and this particular

LT. COL. A. E. WHITE
National President of the Society

meeting that they broke away from their New York engagements and came down to be with us at this particular time.

I never quite realized before that the lot of the average actor and actress was altogether in many respects undesirable. I always thought that those one-night stops which they had when they traveled from city to city must be a joy and a pleasure; but I feel now as though possibly I can sympathize with them somewhat because it has been since a week Friday that I left Ann Arbor, and I don't think I have spent 24 hours in the same place since I left there. And although it has given me great pleasure to be with the different chapters, it has been rather hard to be always running in at 11, 12 or 1 o'clock and getting into another town the next day. I told the first chapters I visited that I regretted very much indeed that I was unable to give them a perspective of what was going on in the various

*Director department of engineering research, University of Michigan, Ann Arbor, Mich., and national president, American Society for Steel Treating.

chapters in the country. It has been my good fortune to visit chapters in Detroit, Cleveland, and Buffalo. I visited chapters in Chicago last spring, and on this trip I am visiting a number of chapters in the East. I felt I was getting more out of the visits than the chapters were getting out of me. I think that is absolutely true. Again I regret as I visit Philadelphia at this time that it was not possible for me to have visited it earlier and to have carried back to the chapters that I have visited the inspiration which I am receiving here tonight. I think I can say without any undue embarrassment to any of our other chapters that I have visited, that if this meeting is a sample of the meetings you have monthly—and reports that we have from Philadelphia indicate that it is—you have without any question the leading chapter of the American Society for Steel Treating.

A week ago Monday night, when I was in Boston, they told me that they were conservative in Boston, and that they didn't want to go too fast because they might spoil that type which they seemed to be proud of. I talked a little frankly to them because I was born 30 miles from Boston; and I can tell this story because it hits me. A man living in Pittsburgh spoke to one living in Boston, and the Bostonian said, "Where do you live?" The Pittsburgher answered, "In Pittsburgh." The Bostonian said, "And where is Pittsburgh?" The Pittsburgher answered, "Anyone who lives 30 miles outside of Boston can answer that question."

I told them at the Boston meeting that I understood Philadelphia was conservative also, but I was also able to tell them that the American Society for Steel Treating in Philadelphia was setting an example for the other chapters of the Society, which was of a most magnificent type.

I have been impressed, however, as I have visited the various chapters, with the magnitude of our organization. When you stop to realize that one night in each month in the year, with the exception of July and August, there is a gathering of this particular type having, I am sorry to say, only about one-half to three-fourths of the number you have here, but at least a gathering on an average of 100 men, meeting for the purpose of discussing the things we are all assembled here to discuss, it seems as though we have something that is worth while. As I attended a meeting in New York this morning relative to rock drill steel and realized the size and immensity of that particular small piece of investigation and realized also that we might carry this investigation to numerous other lines, I feel that we need have no fear of our particular society's running out of material for topics of discussion.

I must not speak too long for you have three or four very able speakers here tonight, and I note that they have very interesting messages to bring to you. I presume I can use the same plan in speaking to you as young ladies do in dressing—they attempt to get enough to cover the subject, and yet they try to make it short enough to be interesting.

Just a few words with regard to what is taking place in a very few of our chapter meetings. You have all received the January issue of TRANSACTIONS. Various data notes have been introduced, and I believe that the character of these notes, as time goes on, will improve. I think Chicago has done exceptionally well in one case. They have established an educational program with night school classes in Armour Institute and in Lewis Institute, and these classes are graduated. The instructional work is done through co-operation with the American Society for Steel Treating and the various

officers and members of that society. In some places round table talks have been most interesting. I understand you had one here the other night, or at least a discussion of one.

The Hartford Chapter I find to be in a particularly healthful condition, and probably one reason they get along so well is because at the very beginning of the year they arranged a definite program for each meeting—it is definitely known what subject is to be talked on and the date for the meeting is definitely set. They have a chapter of over a hundred, and with Hartford being not a very large city, that speaks very well for it. I was given to understand while there that the meetings in Providence might probably be sparsely attended. Of course, there is more or less contention between Hartford and Providence as two of our large machine companies are respectively located in these cities. To my surprise there were 100 to 125 at the Providence meeting on Monday night. There were 100 at the Bridgeport meeting, and over 100 at the Boston meeting; the other places had less. The New Haven Chapter I anticipate will have an increased life now because of certain changes which have taken place. Springfield had an attendance of about 50, in spite of a New England blizzard which started in about 3 o'clock in the afternoon with the prospect of tying up the city at 11 o'clock at night. An attendance of 50 was therefore considered exceptionally good.

It is certain now that the coming convention in 1921 will be held in Indianapolis. I received word that the National Secretary and National Treasurer were leaving Sunday for Indianapolis to complete final arrangements. It was rather desired to hold the convention in Detroit, but the conditions which prevented the meeting in Detroit were the lack of proper hotel facilities and proper convention hall. Cincinnati has made a most excellent bid for the convention, offering special inducements, which made the choice rather difficult.

Our society has grown tremendously. There is no question but that the Philadelphia Chapter has grown tremendously; in fact, I have been given to understand that the Philadelphia Chapter has increased something like 300 per cent since last September. That represents tremendous growth, and the credit rests entirely with your officers, committee, and yourselves for having put this thing across in this way. The National Secretary reported to the postal authorities that we had 2959 members in the Society at the present time—nearly 3000 members. He also told me that our treasury was in a very fair condition for a technical and educational society, namely, $2800.00 in the treasury with only $600.00 owed, leaving a free balance of $2200.00. It is not possible to do very much with that sum; but it means that you belong to a society that is absolutely free from debt and is able to discount its bills, and that there will be absolutely no necessity for raising the dues or asking for special subscriptions from any of you. That I think is an excellent state of affairs to present at this particular time.

I don't know that I have much more to say. I am afraid that if I say much more the skirts will begin to lengthen and the subject will be inappropriately clothed. I extend to you the greetings of the national office. I want you to feel that the national officers are your servants, honored to do your bidding, that we want to make the Society the Society you want it to be. If we can be instruments to put those things into effect that you want put into effect, we want you to realize that we stand ready to do your bidding in every respect.

METALLURGICAL PROGRESS OR PROGRESS IN STEEL TREATING

By Dr. Joseph W. Richards*

(A Paper Presented Before the Philadelphia Chapter)

In this article I do not purpose to tell you any of the schemes of the ancients or of the moderns for the treatment of steel. I want to take this opportunity to discuss the subject of metallurgical progress—progress in steel treating, if you like.

The ancients tried out things by rule of thumb, hit or miss. Once in a long while they hit upon something new that worked, and they then made

DR. JOSEPH W. RICHARDS
Professor of Metallurgy, Lehigh University

some progress. At the present time we work intelligently. Our friends the instrument makers give us instruments for control, which tell, for instance, the exact temperatures instead of our having to guess them with the eye. We have now a great deal more information handed down in books, and know more of physical and chemical principles, so that our experimenting is much more intelligent, and we are considerably ahead in that line of anything which the ancients could do.

To go one step farther, however, let me explain the way in which still more fundamental work can be done toward making progress in steel treating. It is my opinion that the first requisite to make progress in any particular operation is to know "Why is works?" and "How it works?"—"Why" and "How." When we attempt to find out "Why" and "How," we get back of experiments, of works experience, back down to the foundation principles

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which seem very far away from that in which we are ordinarily interested. These foundations of the "Why" and the "How" are in most cases the detailed physical and chemical properties of the materials we are working with, and a deep understanding of the physical and chemical operations to which we are subjecting them. We have to go away down into the cellar for the fundamentals of the subject.

Following are some illustrations of this. For instance, in my book on *Metallurgical Calculations,* there is a chapter on the thermophysics of the elements, their temperature relations as regards their change of state. Let us take these up with regard to iron for instance. First of all there is its specific heat, which means the amount of heat required to raise the temperature of a certain quantity a certain number of degrees. If you look in the books on specific heat of iron you will find some good information about it, but this information is limited to pure iron and one or two samples of steel. What we ought to have is the specific heats of all of the various kinds of iron or steel, the standard qualities which we are using. Now, why do we want to know these? What advantage is there in knowing how much heat is required to bring a certain weight of iron or steel up to a certain temperature? Our information in this line is very fragmentary; a liberal statement would be one-tenth of what we ought to know.

You have a furnace to heat 100 pounds of iron to 800 degrees in order to quench it. You burn gas and the gas bill is sometimes pretty high. How efficient is that furnace? Do you know? You put the iron in, burn the gas, get the result, you have to foot the bill. If you compared the caloric power of the gas with the amount of heat you put into the iron, you would find it possibly about 20 per cent, in other words, your furnace is 20 per cent efficient. When you know that, your first impulse is to get busy and try to improve it. You have an 80 per cent margin to work on. There is an immense incentive to make an improvement when you know what the maximum possible is, and know how little you have been getting. If an electric furnace it put on to that same job of heating up a certain amount of steel to a certain temperature, you calculate the heat value of the electric current used and find that the furnace is 40 or 50 per cent efficient. That is pretty good, and yet you might be dissatisfied with that. Could it be improved upon? If you look at a number of these furnaces you will find that most of them are painted a nice neat black. You then recall from your physics lessons in high school days that black is the best color for radiating heat. Over 50 per cent of the heat has been radiated. "Guess we can save some of that; we'll paint it white," you say.

This reminds me of a personal experience which will illustrate this point. Last winter I bought a new house and moved into it. It had hot water heating. All the hot water pipes in the cellar were painted black and the radiators upstairs were painted white. I got a painter and gave him some dead black paint and some aluminum bronze paint. I had him paint every pipe in the cellar white and every radiator upstairs black. The steel business could apply some of these principles with economy.

Suppose you were melting steel. You might be curious to know how much heat it requires to melt steel. You know it takes a lot of coal, gas, or electricity; but how much heat is required in melting steel? Where could you go for that information? The only place would be to some book of tables which contains determinations made in physical or chemical laboratories. You would look for the latent heat of fusion for steel. How-

ever, it does not exist anywhere; it has not been measured. I made a guess at the latent heat of fusion of pure iron—66 calories per kilogram and probably this is within 10 per cent or 6 calories of the correct value. We don't know how to calculate the latent heat of steel with different percentages of carbon in it. An experimental study ought to be made by someone on the latent heat of fusion for different kinds of steel; we ought to have something more than the latent heat of pure iron, and that only a guess. With the help of the Bureau of Standards, college laboratories, and private industrial laboratories we might get some of these figures.

The Bureau of Standards published last year considerable data on the physical and chemical properties of copper. This was very complete. I am very much interested to know how the collection of data on iron is coming. They will collect all information found anywhere in print, and give it to us. I am sure they won't have much information on the latent heat of fusion of steel but still I believe that is to come.

When you bring steel up to the melting point you have to supply a good many calories in that temperature, and you supply them at an efficiency of about 10 per cent of the heat value of the gas you are using. Electricity however, has this advantage over gas heating that the electric current is just as efficient at 1500 degrees centigrade as it is at 200 degrees centigrade. Its efficiency of conversion into heat is practically the same at high temperatures as at low. You will have to make a detailed study of each furnace to find what its efficiency is; next you will study how it can be improved; then you will have the fundamental facts on which almost certain progress can be based.

Recently I read a paper on arc welding of iron, and it was very interesting. The author discussed where the electrical energy went to, and what per cent was used in melting the iron. He used the guess I had made on the heat of fusion of iron, and found that 40 per cent was used in the operation of melting the iron. He said some of the iron vaporized. How much electrical energy was used in vaporizing the iron?

We know a great deal about the heat of vaporization of water. Books are full of that, but what is the latent heat of vaporization of iron? That is another guess I made in *"Metallurgical Calculations."*. I though it was important to know, so I made a long-shot guess at it. It may be 20 per cent incorrect in value, but something near the truth is better than no idea at all. He figured that 10 per cent of the electric energy was absorbed in vaporizing the iron.

In regard to the latent heat of vaporization of metals, this value has been determined for only two, so far as I know, out of a possible 30 or 40. Here is a field that needs a great deal of experimental work, if we can only get somebody to do it, either government experts or private laboratories. In general this work has heretofore been done by college laboratories, the professors working for the pleasure of the work, and freely publishing all they found. Book after book has been published on chemical and physical constants, and probably three-fourths of all the data has been furnished by college and university professors and their assistants.

Another line which is a little further removed and which does not touch steel treating particularly, is the vapor tension of metals. They have tension just as much as water has. You can boil them, and below their boiling point they have vapor tension down to their freezing point. I have even

calculated their vapor tensions at zero degrees centigrade. A paper was read in New York recently at the meeting of the American Mining and Metallurgical Engineers on "Heating Steel in Vacuo." The author said that in some cases iron vapor condensed, and the deposits contained manganese and copper. He also found in some specimens that iron volatilized from one part of the specimen and deposited on another part a little way off, showing there were present two kinds of crystals of iron, having different vapor tensions. You will not find much about this in books. But in 5 or 10 years we will wonder how we ever got along without knowing these facts, because they concern operations which are frequently done, and they help to explain their "Why" and "Wherefore;" yet at the present time we have almost no information at all about them.

Another thing we might discuss is the question of the thermochemistry of metals, for instance, the heats of combination of the metals to form alloys. We know the heat of combination of hydrogen and oxygen to form water; but we do not know the heat of combination of copper and zinc to form brass. If we knew the heats of combination of the various metals, these would probably give us some indication of the stability of their alloys, which information would be very useful.

Another topic of interest would be the equilibrium of iron and iron oxide against carbon monoxide gas. How quickly will various alloys oxidize in an atmosphere of carbon dioxide? Quite a long paper was read recently in New York on the question of the equilibrium of iron and iron carbide with oxygen and the iron oxides. Still another subject for investigation would be heat conductivity, or the power to conduct heat. Where does that come in? First of all, where could we find data about it? If we look in books of tables, we will perhaps find a little data on the conductivity of iron at low temperatures. What about it at high temperatures? When we heat a piece of iron, it heats from the outside. The heat is transferred from the outside to the inside; the rate of transfer depending upon the heat conductivity. If we have the proper data on the heat conductivity of iron at all temperatures, we can calculate how quickly the iron would heat up. You say "We can find out anyway." So you can by experimenting, but you should always check experiments with engineering calculations if you have the data. And suppose you can't make the experiment? You can calculate many things. An engineer calculates a bridge before he builds it. You can get ahead of the game if you have the proper data. Heat conductivity will help to calculate the rate at which metals heat.

Another problem is heat emissivity. At what rate does iron radiate heat? The Bureau of Standards has been working on this. What advantage would there be in knowing the rate at which it radiates heat at different temperatures? Suppose you take a piece of heated iron out of the furnace and start to work it. It cools from the outside. The inside can only cool by transmitting heat from the inside to the outside. This depends on two things—heat conductivity and heat emissivity; the latter radiating it from the outside. If we had these data complete, we could calculate it for any kind of a piece of iron, of any size and any temperature. Before we experimented with it we could calculate at approximately what rate it would cool. By this method of getting the fundamental data you can often predict what is going to happen; you can project into the future and tell what is going to happen before you try.

Let us consider the electrical conductivity. We know the electrical conductivity of iron at low temperatures, up to red heat. We want data beyond that very much; we want to know the electrical conductivity of melted iron. Electric furnaces use melted iron as their resistor, the heat developed being dependent on the resistance of melted iron. What is it? I remember about 10 or 15 years ago there was no figure published. I made a guess, a long-shot guess. I extrapolated the value of the electric conductivity of iron in the solid state at red heat up to the melting point. Some other metals double their electrical resistivity at the melting point when melting, so I halved the conductivity. I came within 10 per cent of the value afterwards determined. My guess at least gave me something to go on with; and, anyway it was not such a wild guess.

There are such things as critical constants but no one knows much about them. Water has a certain critical temperature at which the liquid passes into the vapor with the same density. There are critical temperatures, critical pressures, and critical volumes. I do not think we know them for any metals, but they all have them. I tried to calculate them for mercury. What use are they? When we want to calculate many of the chemical properties of metals we can calculate them from the critical constants more easily than from anything else. In fact this is true of many of the physical properties of the elements. If we had those critical data we could theoretically go back and get the specific heat, the latent heat of fusion, the latent heat of vaporization, etc.

There are a few other things I wish merely to mention; one is the subject of gases in steel. We know that water dissolves gases but if you look in books you will find that water dissolves oxygen, carbon dioxide, and nitrogen and the different amounts given at ordinary temperature and at higher temperatures. Look in books to see how much oxygen, carbon dioxide, carbon monoxide, or nitrogen, iron will dissolve. It dissolves them. Most metals dissolve gas. We know that from experience; but how much? How is it given out? Under what conditions can it be frozen out? We have no information at all of a quantitative nature parallel to what we have for water. So we want to determine it. If we had that data we would be a long way toward settling the question of the presence of gas in metal—in solid metal—and blow holes in castings, etc.

Another subject is the viscosity and fluidity of metals. We should know these in absolute numbers; we should know the value in absolute C. G. S. units. I looked in Landoldt and Bornstein's book of tables under this subject, and found that mercury was the only metal mentioned. When we consider how many metals are cast into castings, and how important is the fluidity of metals, how they have to run up into little narrow cracks—if we only had viscosity or fluidity data at different temperatures, we would know the reasons why they behave as they did at different casting temperatures. What an immense amount of exact information is to be obtained, which we do not have at the present time.

I almost hesitate to mention anything about the alloys of iron because there are so many of them. We do not have complete data on iron itself; the alloys are practically all outside; all unknown. The valuable properties we know about pure iron are yet to be determined for its alloys.

There are a couple of other things I might mention. X-ray pictures through iron. There is a line of investigation for someone. In fact, if we could take pictures right through iron, they would reveal its internal struc-

ture, blow holes, and nonmetallic inclusions. The General Electric Co. is now working on this problem and we can look through ½-inch of iron and see its internal structure. With new machines now being perfected it is expected to be able to see through 1 to 2 inches of metal. Any hidden defects could probably be detected without any damage to the tools.

Another topic which may come up in the future is X-ray interference pictures. We can take a photograph of a crystal which will show the molecular structure. A crystal of iron has had its molecular structure pictured. The points shown in the photograph indicate the atomic grating or scaffolding. There is a field there for the investigation of steels which are other than pure iron, to see if we can find what effect sulphur, phosphorus and other elements have on the molecular structure. In the future we may simply apply this method to the alloys of iron to determine why they act as they do. It will give us further insight into the "Why" and "Wherefore."

DISCUSSION OF DR. RICHARD'S PAPER

MR. WALKER: In my experience with steel the question of rust prevention has come up. Various trades seem to have considerable difficulty in preventing rust. I got into conversation with a man on the train the other day and we talked from Cleveland until the train arrived at Springfield. This gentleman thought rust formation might be prevented by the kind of heat treatment given. If this is so it would be a good thing for other lines of business. You often find underneath a coat of paint that rust formation takes place. This would be a good case for structural steel work, and it would be a good field at some future time for heat treaters in the line of structural steel.

MR. BROOKE: I was specially interested in one phase of the subject discussed by Dr. Richards, that which comes up in designing furnaces for heat treating. We have found a difficulty in obtaining specific heats of the metals of the steel group at normal temperatures, while accurate curves showing specific heats against rising temperatures up to, say 1800 degrees Fahr. are extremely difficult to obtain.

Another difficult datum to obtain is the rate of absorption of various metals and the influence on this of the relation of mass to surface to surface exposed, for any particular piece of the steel. The variation of the latter relation can be seen by taking, for instance, a 15-ton gun ingot when the relation of mass to surface may be as high as 250 pounds per square foot, while in a small casting this relation may easily be only 7 pounds to the square foot.

This information is of special importance to the engineer in designing a modern electric heat treating furnace, so that he may work to a definite and accurate time and heat cycle. It is of importance to the metallurgist in charge of heat treating so that he may know accurately when his work is thoroughly soaked.

There is an important economic feature in this. It has been common practice, especially in the steel industry to soak the steel to be treated. This practice is usually a matter of playing safe, because there has been no true method of ascertaining when the steel itself is at the desired temperature throughout the whole of its mass. The length of soaking is defined by past experience and playing safe at the expense of fuel consumed.

With the modern electric furnace, in which the heat gradient is low and equipped with modern control instruments, soaking for the above reason is eliminated as a two-point instrument, recording the temperature of the uniform source of heat against the temperature of the work, gives two curves which will converge as long as heat flows from the former to the latter. As soon as these curves are parallel, there is no longer any flow of heat and the temperature of the work must be uniform throughout.

Dr. Richards has started some excellent technical propaganda and I am sure he will be pleased to hear that one of the large heat treating furnaces now being installed in the Philadelphia vicinity, is to be painted on every one of its 17,000 square feet of surface with perfect white enamel.

DEVELOPMENT OF MEASURING INSTRUMENTS FOR METALLURGICAL USE

By Morris E. Leeds*

(A Paper Presented Before the Philadelphia Chapter)

The American Society for Steel Treating is a young one and most of its members are young, but in the brief span of its existence a great change has come over the practice of heat treating. The old-fashioned heat treater with his inherited traditions and prejudices practically held the field a very few years ago. That old type of man is fairly well represented by one I knew in a factory not very far from here not many years ago, who said that although he could not tell the temperature of a piece of steel with anything like his father's precision, he could nevertheless with the unaided eye determine with greater accuracy than with any "phrenometer" at what temperature the steel should be quenched. I do not wish to underrate the skill and achievement of such as he, but when we realize the tremendous demands that have been made on the industries in which heat treating performs an important part during the last few years, we realize how very fortunate it is that the art is now resting on a more secure foundation.

Heat treated steel products enter into our economic life to such a tremendous extent in value of material, in range of uses and in range of sizes from armor plate to parts for watches, that it is imperative that the art of heat treating should rest on a secure foundation of ascertained scientific facts. You are to be congratulated on having played a very important part in bringing about the transition from dependence on inherited tradition to soundly based engineering.

Our chairman mentioned something about the part which instruments play not only in the scientific side of this work, but also in its application in the factory. I hardly need to remind you of that; but I think that it is true in this particular field that there is hardly a step in any direction which is not accompanied with some kind of measuring instrument or laboratory apparatus. From the original scientific work in laboratories on through actual operations in the factory you are using in some manner measuring or other instruments. Temperatures are to be measured, critical points determined, chemical analyses made, hardness, tensile strength, elongation and many other properties determined—for all of these instru-

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ments are needed. So I want to devote the few minutes at my disposal to telling you something about the Association of Scientific Apparatus Makers of the United States, to which the chairman referred.

A much younger society than yours, we envy you your strength, your members and your enthusiastic meetings. In comparison we are a very feeble folk in all these respects, but like you we are associated for the advancement of our art, and like you we want to be of service; thus we want to bespeak your co-operation in helping us to accomplish these ends. We are divided into several sections. The one nearest to most of your work is the Pyrometer Group. We include in that practically all of the manufacturers of pyrometers in this country, and we are associated for the purpose of improving that branch of industry so that we can render better service. You might be interested in some of the particular problems we have had under consideration.

One that early claimed our attention was the possibility of standardizing thermocouple materials. If it should be possible so to standardize these materials that all couples made of any particular combination, for instance, iron and constantan, would show the same temperature electromotive force relation throughout their range, then all such couples could be used interchangeably with any reading or recording instrument calibrated for iron-constantan couples. You could interchange couples, whether from the same company or not, in the same way as the microscope of one manufacturer can be used with the objective of another. We found, however, that several standards were in use, and so much material was out that it was not practicable to standardize iron-constantan. It is possible to make a partial standardization of platinum and platinum-rhodium. Copper-constantan couples are coming into use for low temperatures, and a standard electromotive force temperative relation for these has been adopted, to be used by all makers. Chromel-alumel is also standardized, and if new couple materials are introduced it is expected that they will be standardized.

Our association hopes to publish a journal. We have little prospect of having as successful a one as yours from the standpoint of volume of matter printed and amount of advertising carried. The production of good instruments in the United States will be stimulated by having a good journal devoted to the subject. We are developing the plans for this journal in close co-operation with the Bureau of Standards and the National Research Council because we wish to make sure that the journal shall not become simply a trade organ, but that it shall be edited under the control of people interested only in advancing the art of instrument making in the United States, who will see to it that it is used for presenting new and worth while designs and information in regard to instruments, no matter from what source that information comes.

A subject on which we should particularly like to have your interest, and perhaps assistance, is the tariff. As we see it, certain branches of instrument making practically will be impossible in this country unless they are protected and pretty well protected. We do not see how the makers of optical glass, for instance, who had done almost nothing up to the time of the war, can continue to make optical glass successfully and assume the expenses of developing and producing the new kinds of glass needed in small quantities for making optical instruments unless they are in some way supported. I wonder whether you realize how exceedingly important optical glass is and how wide a range of measuring instru-

ments are absolutely dependent on it. Every instrument which has anywhere about it a small telescope, microscope or prism depends on the optical glass manufacturer.

I heard the statement made a short time ago, and I have no reason to doubt its correctness, that if it had not been for some considerable stocks of optical glass in the United States when war started, and supplies from the Allies, we should not have been able to make effective use of the guns on our battleships and land batteries because we should not have been able to make instruments with which to aim them properly. That is just one illustration of how the little technical field of instrument making links itself up with matters of great national importance. We believe that the technical development of our manufacturing processes in the United States cannot proceed on a really sound and healthy basis unless we also produce the instruments on which these processes to so large an extent depend.

It is not only in these rather important matters of policy that we want your interest. As individual instrument makers we want your co-operation in working on the particular instruments that will meet your special problems. We can study the characteristics of instruments and the fundamentals of design in our shops and with the help of the Bureau of Standards and other scientific laboratories, but we cannot give them the particular forms which will best suit them to meet your conditions unless we have your co-operation in presenting your problems and needs. In this respect, I think more than any other, the members of your Society and the members and representatives of ours can work together to mutual advantage so as to develop the great industry with which you are associated and the little but very important one which interests us, and so play our part in promoting the technical development of the country.

WORLD CONDITIONS AND THE DEVELOPMENT OF FOREIGN TRADE

By Richard Spillane*

(An Address Before the Philadelphia Chapter)

The speaker has just come from a dinner at the Bellevue Stratford hotel and for which he had a fair share of responsibility. Probably it was the most remarkable dinner that ever has been held in this city. We had practically all the foreign students of the University and other educational establishments of the metropolitan Philadelphia as our guests. Fifty-two nations were represented there and practically all of their native costumes. This gathering was by design. We wanted to draw the people of the earth closer in their relation to Philadelphia and to the United States. We want to use the basis of hospitality to promote good will, education and trade. It is proposed to have a gathering of this sort every year. It is also proposed to take these students into all of the large banks to see how the animal performs. It is further proposed to take them into the Midvale Steel & Ordnance plant, into Disston's Saw Shop, the Miller Lock, the Stetson Hat, and any other establishments here that will broaden their knowledge of the works of America. We are going to endeavor to influence Boston, New York, and all of the other centers of education in this country to which the foreign students flock, to follow our example—and all on a peace basis, on a basis of good business.

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I don't know whether it is too far a cry to say that out of gatherings such as this of tonight and the others that will be the natural attendants to that, that a great deal of trade, a great deal of business—even in your lines—will develop. We have only a hazy idea of the wonderful transformation, reformation, and majestic change that has come over this world in the last 20 years. If anybody had said in 1876 when Mr. Bell explained the telephone in this city of ours, that in 1920 for example, the human voice or a message would float over the seas on an ethereal wave, that man would have been considered crazy. If any one had prophesied that it would be possible to fly across the seas in one-half, possibly one-third, or maybe one-quarter the time it now takes the fastest ship, he would have been a dreamer.

More progress has been seen in the last 20 years than was seen in the previous 200. If you think of the phonograph, or think of the wireless, or of the telephone as it has been developed over what it was 20 years ago; if you think of all that has come to pass in the last 20 years, it is not too much to say that in the next 20 years the progress will be even greater.

You are going to have wonderful works of development if this country of ours meets the task that is going to be put upon it within the next few years. We will have to do a great work of financing; we will have to finance Asia, Africa, South America, Central America, and Europe. We will have to dig into our socks, stretch the dollar; we will have to do works of legerdemain with money; and we can do it if our men of finance measure up to the genius of the American man.

I was over in New York recently and had laid before me a project in South America that is colossal. I would have thought it was visionary but for the fact that the man at the head of it is of proved greatness, and the financiers interested in it—well, they stand second to none in America. The man is William Braden of the Braden Copper Co., and financial secretary of the Guaranty Trust Co. I went over the reports of the geologists, and unless these men are mistaken—and they had reports of 40 of the most eminent in the world—they have the greatest quantity of oil known. The original pool was in south Bolivia and north Argentine—one pool—another was in west Argentine and three more in south Argentine. They have one section of country in Bolivia of about 5,500,000 acres. It is in a section so removed that although the natives have been using the oil for God knows how long—a 100 years surely, maybe much longer—although they have been using seepage oil for illuminating purposes, there has been practically no development. It is probably a far greater oil pool than that of Mexico which is a mine.

These people contemplate carrying ocean ships 1000 miles up the River Plata and its branches, building 1000 miles of railroad, building great refineries, and other projects of the same character, but not so much in their immediate neighborhood. Their initial outlay they expect to be $50,000,000; but that will be only a starter.

If this plan comes to accomplishment you can expect argosies of business in the South Atlantic and South Pacific comparable only to what you have in the North Pacific and North Atlantic today, for if they have the great element of power, oil, in the quantity that seems probable, this is going to revolutionize trade instantly in that part of the world. And it will create a demand for steel such as you never expected from that quarter.

According to the plan of the youths, of 52 foreign nations—youngsters—the pick of their country, will be sent here to be educated in this land of ours. About 600 foreign students now are in the metropolitan Philadelphia; about

6000 in the United States. I think it is about time we showed them our hospitality, showed them our friendship; showed them the inside of all of our structures that it is necessary for them to know, and have them go back to their own lands as boosters, agents, and salesmen for this country of ours. I think this is about as easy and cheap a way for us to "sell ourselves," as the saying is, to the foreign customer.

Very few I believe have any conception of what is going to be done in other lands within the next half century, or what a tremendous draft there is going to be on this country for material. Some of the projects in connection with China are tremendously big and we will have to do the financing. This should not be bothersome, however, in view of our work in developing the railroads of America, the British, the Dutch, and the French. Those who really put up the bulk of the money never lost anything in the long run. We are in a much better position to avoid some of the pitfalls into which they sank. We are loath to venture into foreign territory; but we have got to do it. This world of ours is sadly mixed. There is no country that is self-contained. We have argued to ourselves that this country was; but it is not. Unless other sections of the earth profit, we are not going to profit to the extent we ought. There cannot be any loss in any section without all sections feeling it to some degree. There can be no work of development, no work of progress in any section of the earth, without our sharing in it to some degree.

You are going to see an era of railroad building in other countries We are not going to see as much in this country as we should; but we are going to see it in other countries to a very great extent. One of the gentlemen going to speak over at that gathering tonight is one of the ministers of China. If the Chinese can get money, and they have to get it, they are going to do great works in hydroelectric development; works of building; works of development of every kind; they are going to make such improvements as will transform that wonderful land in the present century. It is the same to the south of us. The only thing we have to do to avoid trouble is to stay out of war—that is the only thing. I was at the Bellevue Stratford some time ago when Sir Auckland Geddes said that if another war such as the last one, took place in 20 years, civilization would fall. The same thing was said a little later by Lord Grey when a degree was conferred upon him at Glasgow University. The degree was to have been conferred in July, 1914, but something happened to defer its bestowal until 1921. He uttered the exact sentiment that Sir Auckland did. We today are the leaders, industrially, morally, financially, for the world. We will have to be the suppliers for many decades.

No one who knows the real situation in Europe is optimistic. The whole structure there is wrong. Europe is not only divided into more than 40 territorial units with each unit trying in its own selfish way to advance itself to the disadvantage of its neighbors; but it is living in traditions of hate. It is looking backward instead of forward. It is craving the unattainable and ignoring the attainable. It may be an absurd dream, but the only way I can see that Europe will ever settle these horrible wrongs and forget the past is to fabricate a structure somewhat after that which we have here, and have a United States of Europe. If they don't do something of that sort, they will go from worse to worse. You can imagine what Europe is if you can picture this country of ours with its 48 states with each one having an economic barrier against the other. Suppose Pennsylvania could not ship goods into Ohio, or into New York, Maryland, West Virginia, or New Jersey, without

the goods paying tribute at the territorial division to the other country. It is the most horrible mixture of races of the earth. It is the most horrible mixture of hates of the earth.

Many of those people figure the things to do from the ideas and hates of nearly 10 centuries ago, and it is going to be very, very hard to wean them away from their old ideas. All men of prominence who have been abroad and with whom I have spoken, are not one-tenth as hopeful of Europe as they are of Asia, South America, or Africa. We will have to help Europe; we will have to help it largely, not only largely with money, but with material and with philosophy different from that which has obtained there for these many years. Some of the men who have been in central Europe tell me that the civilization of central Europe is at least a century back of that of ours, and that industrially only in spots do they approach anything we have here. But you have a fallow field. There is, however, a wonderful field in foreign lands; and while we will have to do all within our power to aid the people of Europe, not only for their own good, but for our own safety; it is best for us to expend our best efforts on lands where hates are not so deeply rooted and the prospect is far more pleasing.

TESTS OF CENTRIFUGALLY CAST STEEL

By Dr. George K. Burgess*

(A Paper Presented Before the Philadelphia Chapter)

In 1918, the Bureau of Standards had occasion to examine several hollow, steel cylinders made under the direction of W. H. Millspaugh by his centrifugal casting process. The manufacture of these centrifugal castings was carried out under somewhat adverse conditions in two steel foundries which of course, due to the limited experimental nature of the trials, could not have developed the refined technique that practice would give, nor were efforts made to produce high grade steel for these tests.

The cylinders were cast in a machine revolving about its horizontal axis. The outer surface of the castings, of walls from ½ to 3½ inches thick, thus were against the mold and turning faster than the free inner, cylindrical surface which was last to freeze. The outer surfaces were fairly smooth but the interior surfaces were rough.

The results, comparing the several grades of steel in the condition as cast and after heat treatment, are of considerable interest as indicating what may be expected for certain shapes from this method in the production of sound steel, that is, steel free from physical defects and chemical segregation, and thus with practically no waste material to discard. As will be shown, it is also a field particularly adapted to the elimination of forging and boring operations and the substitution for the former of heat treatment to produce the desired characteristics in the resulting product.

In all six castings were examined, samples from which were subjected to the usual mechanical tests both transverse and longitudinal, in the condition as cast and after various heat treatments. The characteristics of the metal with respect to internal stress, density, soundness, segregation, and micro-structure were also studied.

In Figs. 1 and 2 are shown the dimensions of the castings and the location of samples for test, except for No. 7, which was a cylindrical ring of 12

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*Chief of the Department of Metallurgy, United States Bureau of Standards, Washington.

inches diameter and one-half inch wall thickness, from which longitudinal flat tensile bars 12 by 1 x 9/32 inches were taken. The tensile bars from all other castings were standard 2-inch round bars. Samples for chemical analysis were taken from ring turnings for castings Nos. 4, 5 and 7, and for Nos. 1, 3 and 6 from longitudinal borings in zones numbered 1 to 5 from outside to inside of the casting, as shown by the sketches in Figs. 1 and 2.

In Table I are given the results of the radial surveys for hardness and chemical analysis. It will be noted there is a gradual increase in carbon from the outside to the inside surface for all castings, this increase ranging from 0.02 per cent for No. 3A to 0.09 per cent for No. 5. This increase appears to be roughly proportional to the carbon content, or the percentage variation in carbon remains practically constant. The nickel and phosphorus appear to follow the carbon very closely in their behavior as to segregation; manganese and silicon, however, are nearly constant across the radial section; while sulphur, although somewhat erratic, in general is distributed similarly to carbon, as is also copper, although present in quantities less than 0.1 per cent. The hardness surveys, brinell

Table I

Hardness and Chemical Surveys

Casting Number and Wall Thickness Inches	Zone	Brinell	Sclero-scope	Carbon Per cent	Manga-nese Per cent	Silicon Per cent	Sulphur Per cent	Phos-phorus Per cent	Nickel Per cent	Copper Per cent	Chromium Per cent
No. 1	1	186	25.8	.44	.44	.47	.024	.011	2.33	.084	...
	2	186	24.9	.48	.44	.47	.030	.013	2.35	.089	...
3½	3	187	25.0	.46	.44	.47	.032	.013	2.32	.085	.04
	4	187	25.2	.46	.44	.48	.032	.014	2.36	.094	...
	5	196	25.7	.50	.44	.47	.034	.015	2.39	.089	...
No. 3 A	1	160	22.3	.33	.54	.19	.022	.015	2.66	.051	...
	2	164	22.2	.32	.55	.19	.030	.014	2.67	.053	...
3	3	167	22.4	.32	.55	.19	.032	.015	2.70	.051	.04
	4	167	22.6	.34	.57	.19	.034	.016	2.75	.055	...
	5	160	22.3	.34	.57	.20	.030	.017	2.70	.054	...
No. 3 I	1	158	21.9	.30	.55	.20	.031	.012	2.66	.062	...
	2	159	22.0	.30	.55	.19	.030	.013	2.67	.062	...
3	3	158	22.0	.30	.55	.20	.030	.015	2.68	.067	.04
	4	156	22.5	.34	.57	.20	.030	.017	2.76	.068	...
	5	184	23.9	.35	.57	.21	.030	.018	2.70	.065	...
No. 4	0	...	....	.16	.47	.27	.054	.045	....	....	...
	1	125	19.7	.16	.50	.29	.045	.033	....	....	...
	2	...	20.4	.16	.51	.28	.045	.033	....	....	...
2¼	3	128	20.6	.17	.50	.28	.049	.037	....	....	...
	4	...	20.0	.18	.50	.29	.053	.038	....	....	...
	5	121	19.2	.21	.52	.29	.060	.043	....	....	...
	6	...	....	.18	.40	.22	.066	.059	....	....	...
No. 5	1	249	63.5	.64	.56	.65	.033	.014	2.94	....	...
	2	...	60.6	.65	.56	.65	.032	.015	2.92	....	...
3¼	3	248	58.0	.63	.55	.64	.029	.015	2.93	....	tr.
	3	...	55.5	.63	.55	.64	.031	.017	2.93	....	...
	5	245	57.0	.72	.60	.68	.033	.017	2.90	....	...
No. 6	1	164	23.4	.32	.56	.19	.034	.015	2.69	.059	...
	2	166	23.4	.33	.56	.19	.035	.015	2.75	.058	...
3½	3	161	23.4	.31	.56	.19	.039	.015	2.72	.059	.04
	4	167	23.8	.33	.57	.19	.032	.015	2.76	.064	...
	5	191	25.2	.35	.57	.19	.033	.016	2.81	.064	...
No. 7	1	...	....	.22	.54	.26	.026	.013	....	....	...
	2	123	....	.21	.53	.25	.026	.014	....	....	...
½	3	...	....	.25	.55	.25	.026	.016	....	....	...

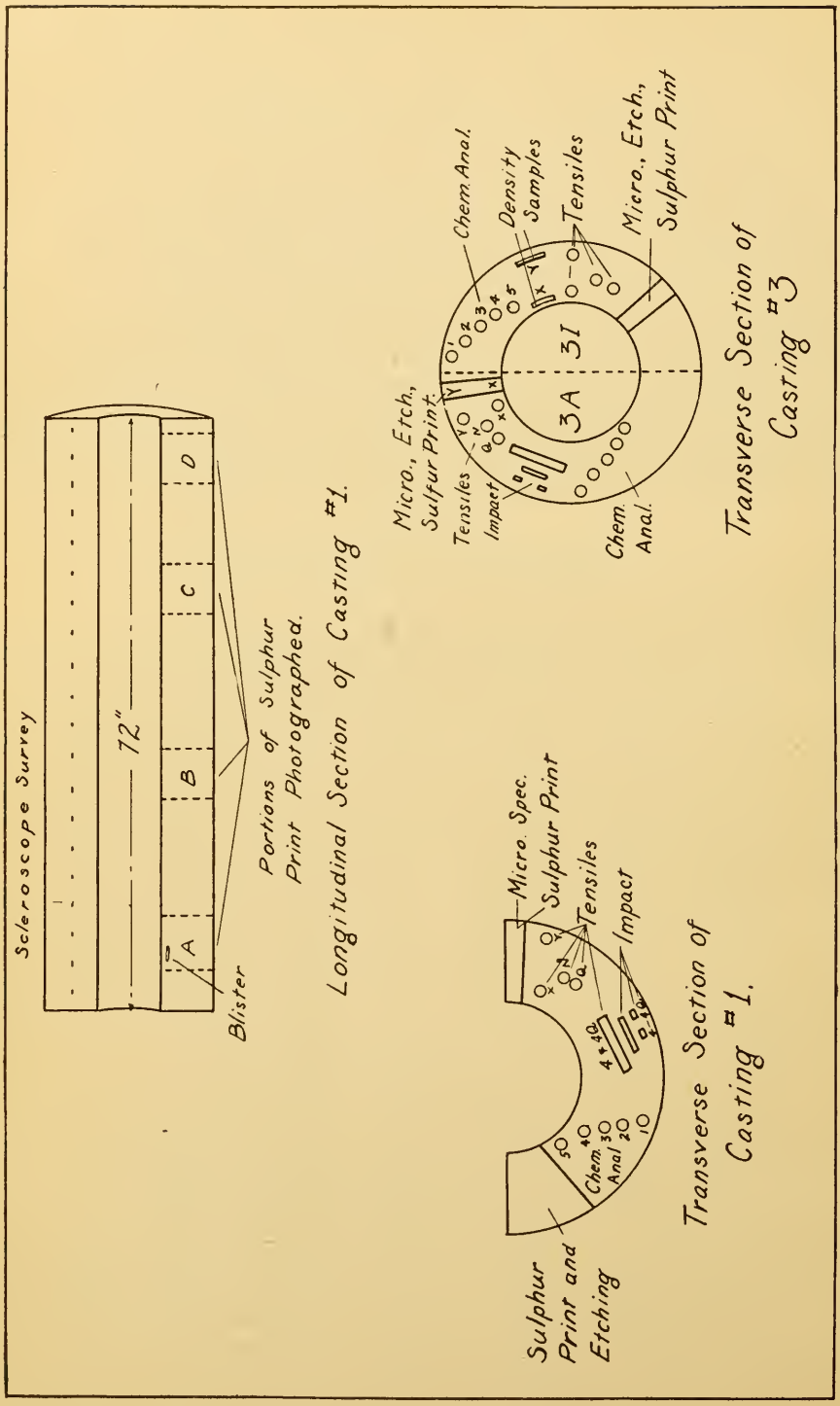

Fig. 1—Test Sample Sketches of Centrifugally Cast Steel Pipe

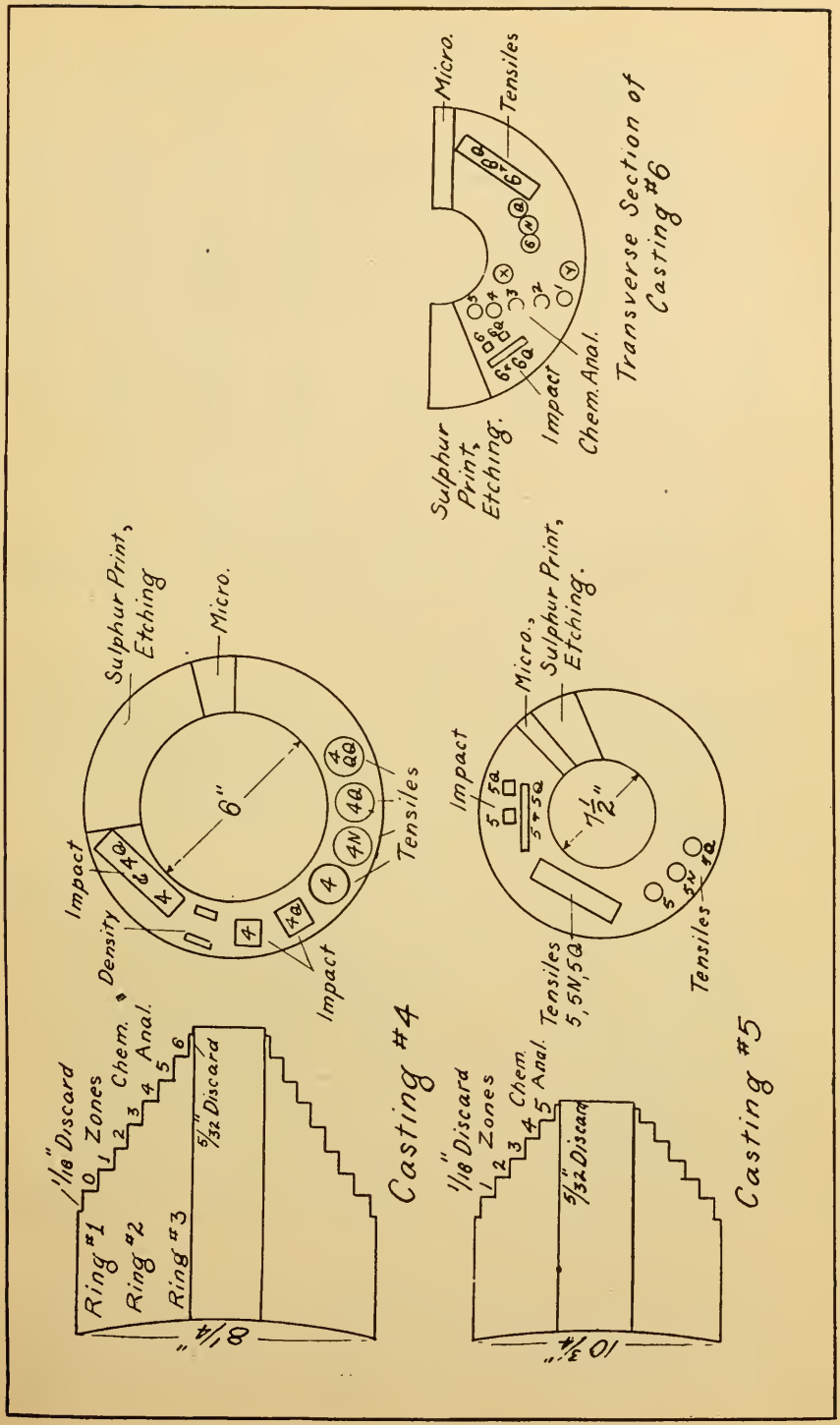

Fig. 2—Test Sample Sketches of Centrifugally Cast Steel Pipe

Table II
Nature of Stresses in Concentric Rings from Castings

Outside Ring	CASTING NO. 4 Before Splitting Inches	After Splitting Inches	Difference inches		CASTING NO. 5 Before Splitting Inches	After Splitting Inches	Difference inches	
Outside diameter....	8.080	8.080	0.020	contraction	10.765	10.750	0.015	contraction
Inside "	7.280	7.265	0.015	"	10.205	10.185	0.020	"
Between punch marks, diameter	7.650	7.625	0.025	"	10.515	10.505	0.010	"
Between tangential punch marks outside	2.030	1.990	0.040	"	2.015	1.985	0.030	"
Between tangential punch marks middle.	2.000	1.960	0.040	"	1.985	1.950	0.030	"
Between tangential punch marks inside..	1.920	1.890	0.030	"	1.990	1.950	0.040	"
Middle Ring								
Outside diameter....	6.840	6.830	0.010	"	9.530	9.565	0.035	expansion
Inside "	6.560	6.550	0.000	.....	9.080	9.095	0.015	"
Between punch marks, diameter	6.920	6.920	0.000	.....	9.345	9.355	0.010	"
Between tangential punch marks outside	1.985	1.985	0.000	.....	2.000	2.015	0.015	"
Between tangential punch marks middle.	1.955	1.960	0.005	expansion	2.005	2.020	0.015	"
Between tangential punch marks inside..	1.900	1.900	0.000	.....	2.000	2.015	0.015	"
Inside Ring								
Outside diameter....	6.790	6.780	0.010	contraction	8.515	8.560	0.045	"
Inside "	5.980	5.975	0.005	"	8.360	8.405	0.045	"
Between punch marks, diameter	6.425	6.445	0.020	expansion	8.160	8.175	0.015	"
Between tangential punch marks outside	1.970	1.965	0.005	contraction	1.985	2.025	0.040	"
Between tangential punch marks middle.	1.955	1.950	0.005	"	1.975	2.005	0.040	"
Between tangential punch marks inside..	1.945	1.945	0.000	.....	1.975	2.005	0.040	"

and scleroscope, follow closely the chemical segregation, the higher numbers occurring on the inside layers. A hardness survey with the scleroscope made midway along a longitudinal section the 72-inch length, of casting No. 1 at 3-inch intervals, shows a gradual increase in hardness from end B to the middle, 24.2 to 25.3, and then nearly uniform hardness for the second half, or from center to end A. The position of the scleroscope survey is shown by the longitudinal section of casting No. 1, Fig. 1. The chemical analysis of the *A* and *I* sections, separated by 60 inches in the *C* casting, apparently shows evidence of longitudinal segregation but this is so very slight as to be uncertain.

A narrow circumferential strip 2 inches long, 1 inch broad, and 1/4-inch thick was cut from the outside and from the inside of a transverse ring from the nickel steel casting No. 3*I* and from the low carbon casting No. 4 and used for determination of density. The results are as follows:

	Grams per cubic centimeter at 23 degrees Cent.	Difference
Casting No. 3*I* outside	7.838	
Casting No. 3*I* inside	7.834	+0.004
Casting No. 4 outside	7.834	
Casting No. 4 inside	7.726*	+0.108

*The low density of sample No. 4 (inside) is probably due to the presence of a series of very fine pits or blowholes in this sample. These holes occur about 1/16 inch from the inner surface of the casting, where their presence was actually observed.

Three concentric rings, 3/8 inch wide radially and ½-inch thick longitudinally, were cut from the No. 4 casting which was low carbon electric furnace steel annealed, one ring from the outside, one midway, and one from the inside of the cylinder. Accurate measurements were made of the outside and inside diameters of each ring, the distance between diametrically opposite punch marks and the distance between three sets of

punch marks 2 inches apart tangentially. A cut was then made by a hand hack saw midway between the 2-inch tangential marks and at an angle of 90 degrees to the diameter measured. When split thus the outer ring contracted visibly but the middle and inner rings appeared to undergo no change. Similar rings were cut from casting No. 5, which was high carbon nickel steel not annealed, measured and cut in the same manner as those from casting No. 4.

The measurements taken before and after cutting these concentric rings and the amount of expansion or contraction in each case are given in Table II and indicate the nature of the stresses in the outer, middle and inner zone. A rough computation gives the compression at outside ring of casting No. 4 as 48,000 pounds per square inch. For No. 5 the compression at outside ring is 31,000 pounds per square inch and the tension at inside ring is 47,000 pounds per square inch. These internal stresses are of the order of the elastic limits of the material, and as would be expected, the outer zone of the casting is in compression.

Turning now to the question of the improvement of these castings by heat treatment, in Table III are given the details of the treatments to which material from their castings were submitted, and in Table IV are grouped the mechanical properties associated with the respective treatments. The location of the specimens is shown in Figs. 1 and 2. It should be recalled that castings Nos. 1, 3, 4 and 7 were annealed as a whole before any tests were made on them, while castings Nos. 5 and 6 were examined first in the condition as cast. The test pieces from 3A

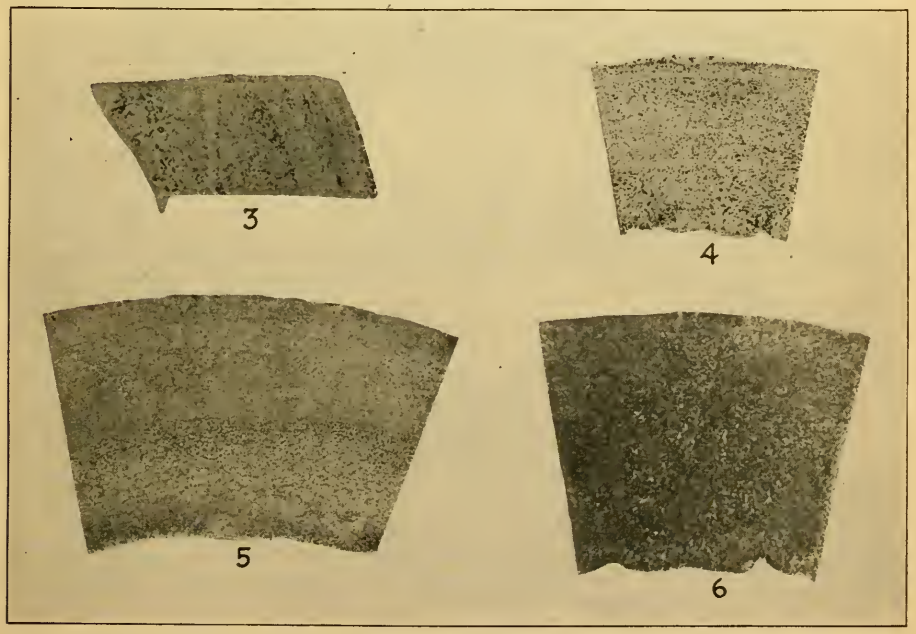

Fig. 3—Sulphur print of a short section of Casting No. 1 showing a high sulphur outer zone and low sulphur middle zone. Fig. 4—Sulphur print of a transverse section of Casting No. 5 showing small high sulphur areas in inner zone and several circumferential low sulphur bands in middle and outer zones. Fig. 5—Cupro-ammonium-chloride etching of transverse section of Casting No. 1, practically free from fir-tree crystals but showing high carbon circumferential bands in inner zone and low in outer. Fig. 6—Cupric-ammonium-chloride etching of transverse section of Casting No. 5 × 1½. Structure is coarse grained with higher carbon areas in inner zone.

and 31 were from pieces of the same casting 60 inches apart. An examination of Table IV shows that most samples show good tensile strength for their composition and treatment and also that there is no marked difference in values for longitudinal and transverse specimens. The values for the Izod shock test are somewhat erratic. The advantages of heat

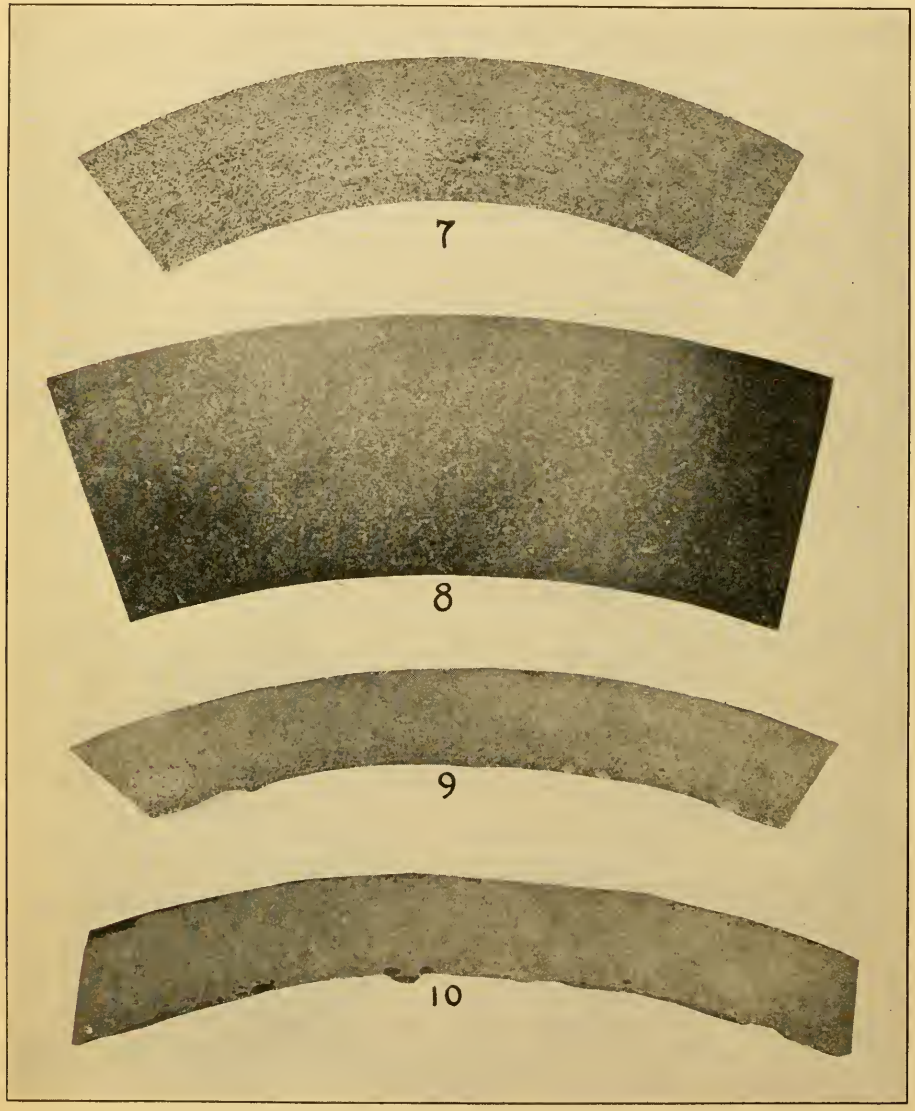

Fig. 7—Sulphur print, actual size of transverse ring from Casting No. 4. Little variation in sulphur content, slightly more along inner edge than outer. Small local segregations visible. Fig. 8—Cupric-ammonium-chloride etching × 2 showing coarse grained structure. Fig. 9—Sulphur print, actual size, of transverse section of Casting No. 7 showing practically no sulphur segregation except at few small spots at extreme inner edge where small surface blow holes occur. Fig. 10—Cupric-ammonium-chloride etching, actual size. Transverse section, full thickness as cast, no machining, showing freedom from ingotism. Small surface blow-holes visible within 3/16-inch of surface. Inner zone slightly higher in carbon.

treatment, notably of the double quench and draw in improving both the resistance to shock and especially the ductility as measured by reduction of area, are strikingly manifest. Certain of these treated steel castings would appear to compare very favorably in their properties with those of forged material of the same compositions. For example, the ordnance requirements for gun forgings are: Elastic limit, 65,000 pounds per square inch; tensile strength, 95,000 pounds per square inch; elongation longitudinal, 22 per cent, transverse, 18 per cent; reduction of area longitudinal, 35 per cent, transverse, 30 per cent. These probably are more than met by casting No. 6*QQ*, Fig. 2, which contains carbon 0.33 per cent and nickel 2.75 per cent; and almost met by others much as 3*AQ* and 3*IQ*,

Table III

Heat Treatment

Designation of Sample	Condition Received	Heat Treatment Given	Temperatures and Time of Heating: Heated then slowly cooled in air — Temp. Deg. Cent.	Held Hours	Temperature when quenched — Deg. Cent. First	Second	Quenching Medium	after 30 minutes Deg. Cent.	Cooled in
1 N	Annealed	Normalized	800–805	2	...	...	.....	...	Air
1 O	"	Quenched and drawn	800–805	2	795–800	...	Water	600	"
3 N*	"	Normalized	890–900	3	...	...	.....	...	"
3 Q	"	Quenched and drawn	890–910	3	845–850	...	Oil	640–650	"
4 N	"	Normalized	910–925	2	...	...	.....	...	"
4 Q	"	Quenched and drawn	910–925	2	915–925	...	Water	450–460	"
4 QQ	"	Double quenched	910–925	2	915–925	885	Water	440–450	"
5 N	As cast	Normalized	750–760	1½	...	...	.....	...	"
5 Q	" "	Quenched and drawn	750–760	1½	760	...	Oil	700–705	"
6 N	" "	Normalized	850–860	2	...	...	.....	...	"
6 Q	" "	Quenched and drawn	850–860	2	825–830	...	Water	675–680	"
6 QQ	" "	Double quenched	850–860	2	825–830	790–795	Water	680–690	"
7 Q	Annealed	Quenched and drawn	875–880	1	875–880	...	Water	510–515	"
7 QQ	"	Quenched and drawn	880–885	1	880–885	845	Water	435	"

*Specimens from A and I sections of No. 3 had the same treatment.

Fig. 1, which contain carbon 0.32 per cent and nickel 2.70 per cent. Again the properties of the casting with carbon 0.23 per cent are high for steel castings of that composition, and in the treated condition are superior to many of the results on hot rolled 0.20 to 0.25 per cent carbon steels and indeed are comparable to those of cold rolled steels of this grade.

It is of interest to note there appeared no flaws or visible defects, other than small blowholes near the inner surface, in the preparation of any of the test pieces for physical or chemical examination. The blowholes noted were always about 1/16 inch from the inner or free surface of the casting. No hard spots were found in any of the castings. Just next the inner surface of all castings, there is a layer not over 1/16 inch thick which appears to contain nearly all the physical and chemical discontinuities.

Sulphur prints and cupric-ammonium-chloride etchings were made on transverse sections of each casting. Some of the sections photographed are shown on Figs. 3 to 10 and represent the coarsest grained and most irregular portions of the sections examined. The 72-inch longitudinal section was finished and rubbed down with fine emery paper and a sulphur print taken along the entire length but no longitudinal segregation was found. At one point a hole or blister 2 inches long and 1/8 inch wide was found 3/32 inch from the inside edge of the casting and a distance of 6 inches from one end. The location of this blister is shown in the longitudinal section of Fig. 1. A nitric acid etching of the entire

section revealed nothing that is not shown in the sulphur prints. Any appreciable segregation in the casting occurs transversely from the outside to inside as shown in the etched transverse section.

Specimens for microscopic examination were cut from transverse, radial or longitudinal, and tangential sections of each casting as received and from transverse sections of the heat treated bars, in other words, after normalizing, quenching, and drawing, and double quenching

Table IV
Mechanical Properties

C and Ni.	No.	Yield Point lbs. per sq. in. Longitudinal	Yield Point lbs. per sq. in. Tangential	Ultimate Strength pounds per square inch Longitudinal	Ultimate Strength pounds per square inch Tangential	Elongation in 2 inches Longitudinal	Elongation in 2 inches Tangential	Reduction of Area Longitudinal	Reduction of Area Tangential	Izod Impact foot lbs. per Longitudinal	Izod Impact foot lbs. per Tangential	Miscrostructure	
C													
.44-.50	IX	54.3	....	91.2	.....	10.5	....	12.1	....	48.8	.....	Fairly fine with coarse	Ingotism Small blow holes
	IY	53.5	....	50.5	.....	9.5	....	8.9	....	.....	.....	ferrite boundaries, few	
Ni	IT	....	56.5	.....	89.5	....	5.5	....	7.5	.....	.....	slaggy areas	
2.32-2.39	IN	67.5	....	93.0	.....	8.5	....	12.5	....	.....	.....	Fine uniform	
	IQ	87.5	91.3	89.0	105.0	4.5	6.5	11.5	14.0	85.2	.....	Very fine uniform	
C	3AX	53.8	....	89.8	.....	7.5	....	12.1	....	252.0	187.0	Fir tree crystals and a few	
.32-.34	3AY	48.5	....	81.5	.....	16.5	....	22.0	....	.....	.....	slaggy ferrite areas.	
	3AT	....	50.7	.....	78.2	....	26.0	....	42.5	.....	.....		
Ni	3AN	59.8	....	95.7	.....	16.0	....	29.3	....	.....	.....	Fine uniform	
2.66-2.75	3AQ	67.5	70.2	98.0	90.3	21.5	20.5	47.4	42.0	309.0	704.0	Sorbitic, ferrite ghosts	
C	31X	52.5	....	88.7	.....	14.8	....	19.3	....	.....	.....	Finer than 3A	Very few slaggy areas
.30-.35	31Y	48.4	....	81.8	.....	27.0	....	41.8	....	.....	.....	Fairly uniform	
Ni	31N	60.5	....	89.1	.....	9.5	....	18.5	....	.....	.....	Fine, uniform	
2.66-2.76	31Q	64.5	....	95.5	.....	21.0	....	29.9	....	.....	.....	Fine, uniform	
C	4	40.0	....	61.5	.....	16.5	....	10.4	....	34.5	48.4	Coarse with thick	
.16-.21	4N	47.5	....	65.0	.....	11.5	....	18.9	....	.....	.....	ferrite veins	
Ni	4Q	60.0	....	79.2	.....	13.0	....	20.3	....	247.0	304.0	Fine, trace of veins	
.....	4QQ	55.0	....	72.5	.....	12.5	....	24.5	....	.....	.....	Fine with streaks	
C	5	48.0	65.7	85.0	84.7	2.5	1.0	1.2	1.0	16.3	16.1	Coarse pearlite	
.63-.72	5N	77.5	....	129.0	.....	6.5	....	5.4	....	.....	.....	Fine slaggy pearlite	
Ni	5Q	96.4	92.3	115.0	113.3	16.5	7.5	21.7	10.5	142.0	183.0	areas	
2.90-2.94													
C	6X	47.5	....	82.5	.....	17.5	....	21.5	....	432.0	.....	Fairly fine; ferrite	
.31-.35	6Y	48.0	....	81.5	.....	17.5	....	28.5	....	.....	.....	veins, slaggy areas	
Ni	6T	....	50.0	.....	83.0	....	16.5	....	22.0	.....	.....	Ingotism	
2.69-2.81	6N	60.0	....	87.5	.....	14.5	....	22.0	....	.....	.....	Fine; trace ferrite ghosts	
	6Q	83.5	85.0	100.5	104.0	16.5	12.5	26.5	24.5	452.0	456.0	Very fine, pitted with holes	
	6QQ	70.0	....	92.0	.....	23.0	....	44.0	....	.....	.....	Very fine, pitted with holes	
C	7N	38.0	....	64.0	.....	35.5	....	52.5	....	.....	.....	Fine, uniform	
.22-.25	7Q	69.3	....	95.4	.....	18.3	....	39.2	....	.....	.....	Very fine, sorbitic, ferrite	
Ni	7QQ	57.8	....	79.0	.....	27.3	....	47.7	....	.....	.....	Very fine, all sorbitic	
.....													

X = inner zone T = tangential Q = quenched and drawn
Y = outer zone N = normalized QQ = double quenched and drawn

and drawing. Photomicrographs taken at a magnification of 50 diameters and some of them are shown and described in Figs. 11 to 26. Each casting was found to contain relatively large ferrite areas, locally decarburized areas, or long ferrite veins outlining very coarse primary crystals.

The most serious of the low carbon areas were found in castings Nos. 3*A* and 6, the latter being shown in Figs. 21 to 26. These areas are not completely eliminated by normalizing and persist even after quenching and drawing but have been almost completely eliminated by the double quench and draw treatment. The normalizing treatment, for the most part, greatly refines the structures while quenching and drawing produces a sorbitic structure with partially diffused ferrite. Structures after the double quench and draw compare favorably with those of large heat treated steel forgings.

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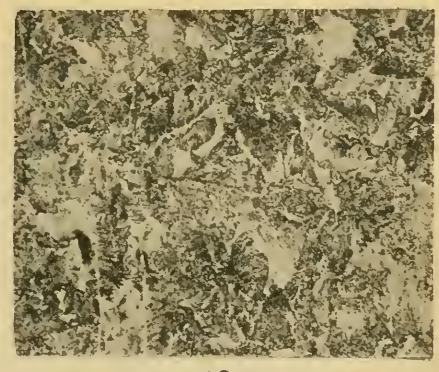

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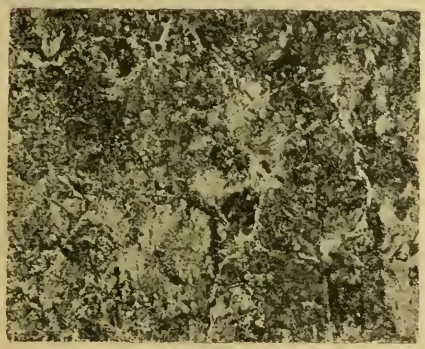

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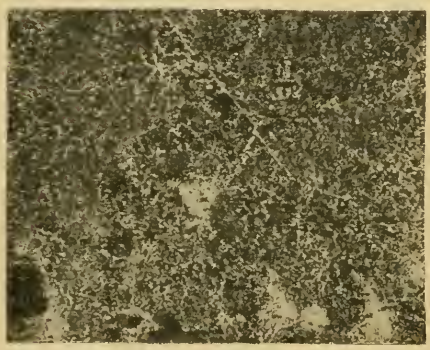

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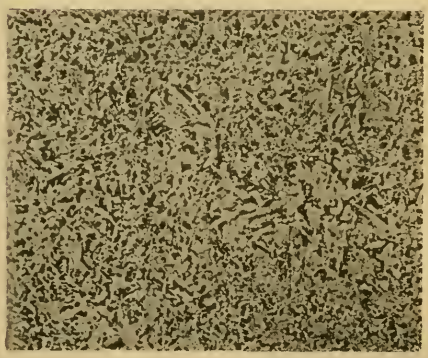

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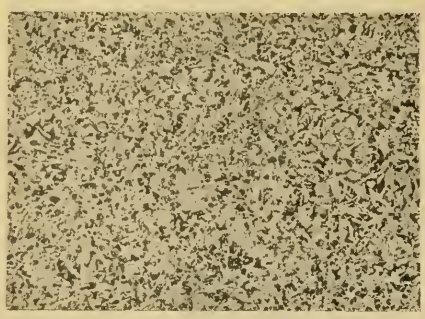
Picric acid etchings × 50. Fig. 11—Transverse section Casting No. 5 as cast. Very coarse grained, apparently not annealed. Average structure pearlite with thin polyhedral ferrite network. Is fairly uniform except ¼-inch zone adjacent to bore where large eutectoid areas about 10 points higher in carbon are visible. Fig. 12—Radial, longitudinal section of Casting No. 5 similar to Fig. 11. Fig. 13—Tangential section of Casting No. 5 with structure slightly finer than that of Figs. 11 and 12. Fig. 14—Casting No. 5 normalized showing refined grain but traces of ferrite areas containing slag inclusions remain. Ferrite network not entirely eliminated. Small blow holes visible. Fig. 15—Casting No. 5 oil quenched and drawn. Sorbitic structure with partially diffused ferrite. Small carbon areas with slag inclusions still prominent. Fig. 16—Transverse section Casting No. 7 as cast. Fine grained uniform ferrite-pearlite free from blow holes and segregation or slag. Well annealed.



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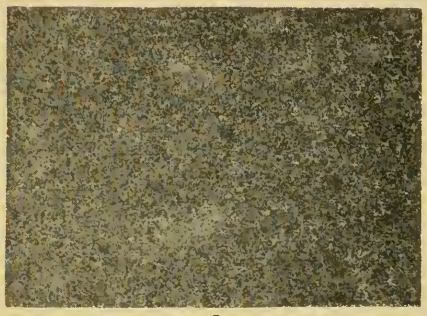

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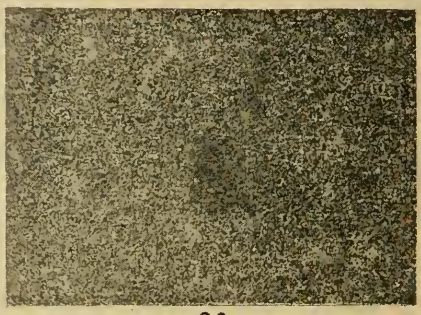

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Picric acid etchings × 50. Fig. 17—Radial section Casting No. 7 as cast. Structure similar to Fig. 16. Fig. 18—Tangential section Casting No. 7 as cast. Structure fine grained but has few areas containing needle-like ferrite particles indicating incomplete annealing. Fig. 19—Transverse section Casting No. 7 after single heat treatment. Very fine sorbitic structure with ferrite network and a few ferrite areas not fully broken up. Fig. 20—Transverse section Casting No. 7 after double heat treatment. Structure fine and sorbitic. Network broken up but many ferrite areas still remain.

Conclusion

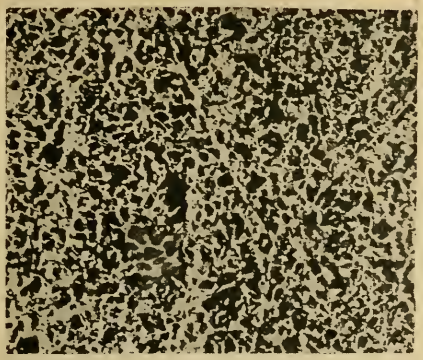
There were examined a miscellaneous lot of five castings in the form of cylinders of wall thickness ½ to 8½ inches made by the Millspaugh centrifugal process. Their composition ranged from two low carbon steels, with carbon 0.17 per cent and 0.23 per cent to three nickel steels averaging in carbon 0.33, 0.46 and 0.66 per cent and in nickel 2.69, 2.35 and 2.92 per cent respectively.

Segregation of the elements carbon, phosphorus, sulphur, nickel and copper appears to exist to a slight extent but only radially, and is most marked in a narrow zone about 1/16 inch depth next the inner surface. Manganese and silicon do not segregate in this type of casting. The greatest carbon segregation was 0.09 per cent in nickel steel of carbon 0.66 per cent and nickel 2.92 per cent and the least, 0.02 per cent in another nickel steel of carbon 0.33 per cent and nickel 2.69 per cent.

The brinell and scleroscope hardness practically follows the segregation.

The only evidence of unsoundness was the presence of small blowholes in the inner zone, usually within 1/16 inch of the surface.

The density across a section is practically constant, the variation being 0.004 in 7.836 grams per cubic centimeter.



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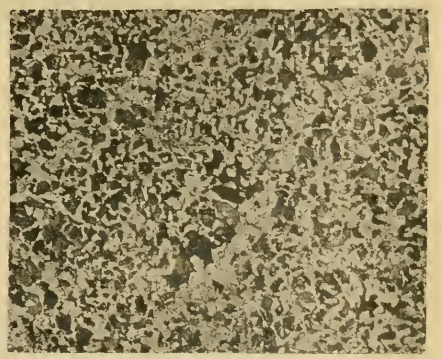

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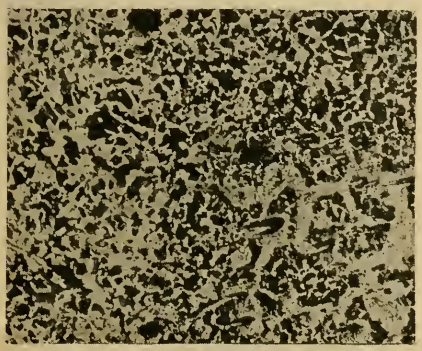

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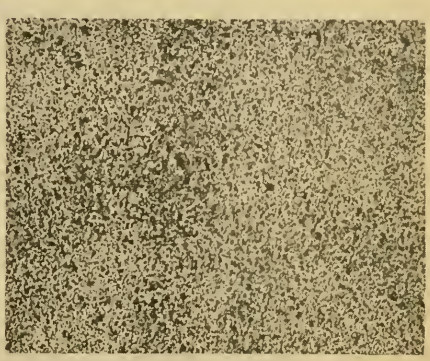

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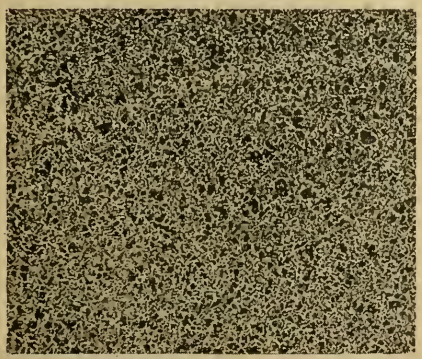

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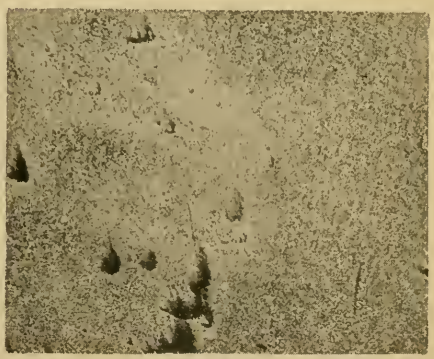

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Picric acid etchings × 50. Fig. 21—Transverse section Casting No. 6 as cast. Although not annealed has fine grain structure. Traces of fir-tree crystals found near inner edges and coarse primary crystals are outlined by thin ferrite network but no slaggy ferrite areas appear. Fig. 22—Radial section Casting No. 6 shows more pronounced fir-tree crystals than Fig. 21. Fig. 23—Tangential section Casting No. 6 shows a cluster of slaggy low carbon areas. Traces of fir-tree crystals found also. Fig. 24—Casting No. 6 normalized. A fairly uniform fine grain ferrite-pearlite structure has been produced. Fig. 25—Casting No. 6 water quenched and drawn. Sorbitic with fine network of undiffused ferrite. Slight traces of ferrite veins, partially broken up found. Fig. 26—Casting No. 6 double quenched and drawn. Although structure greatly refined and ferrite is well diffused, shadowing traces of ferrite veins remain. Area pitted with tiny holes shown.

The mechanical properties show, in general, somewhat greater strength, and elastic limit and resistance to shock but less ductility in tangential than in longitudinal direction.

The internal stresses developed in the castings by this centrifugal process of manufacture, as determined from measurements on three rings from each of two castings, show values of the order of the elastic limit with the outer zones in compression.

The effect of heat treatment in improving the physical properties of the castings is very marked. The results suggest that the properties of such castings suitably treated may rival those of forgings of the same chemical composition.

The microstructure of some, at least of these castings, is better than that of ordinary castings; certain ones show pronounced ingotism or dendritic structure. The nickel steels contain more slag inclusions than is usual in ordnance steel, showing that this centrifugal process may not clear up a basic steel. The ingotism and coarse grained structures of these centrifugal castings can, in general, only be removed by prolonged and repeated heat treatments, in other words normalizing followed by double quench and draw.

The above account is limited to a description of the tests, and no references are given as to the details of the manufacturing operations since the bureau had no first hand information concerning them.

Acknowledgements should be made to the members of the staff of the Divisions of Chemistry, Structural Materials, and Metallurgy who assisted in these tests and in particular to G. N. Nauss, who followed the tests through in detail.

DISCUSSION OF DR. BURGESS' PAPER

MR. BRAYTON: I should like to ask whether that centrifugally cast steel was under very high stress.

DR. BURGESS: It is under that stress due to the rotation. I can see no other cause for it except that it might be due to the actual freezing.

MR. BRAYTON: What would happen if you went to a much higher rotation? Would the metal crush?

DR. BURGESS: Theoretically, yes; practically it would not; you would probably rupture your apparatus first.

CHAIRMAN: I should like to ask Dr. Burgess what he means by normalizing?

DR. BURGESS: I suppose 120 people here could answer that question better than I can. It was our practice to heat the material up to a temperature depending on its chemical analysis, and to hold it from one to three hours depending on the size of the piece, and then air cool.

CHAIRMAN: The reason I asked is because we had a discussion as to the difference between normalizing and annealing. Is there any difference?

DR. BURGESS: I am not open for cross examination.

FIRST PRINCIPLES OF THE CARBONIZING PROCESS—A CONSIDERATION OF THE FUNDAMENTAL FACTS AND FACTORS

By Theodore G. Selleck*

That the art of carbonizing steel has not been reduced to an exact science, the well-informed steel treater is ready to admit; he is also ready to admit that there are strong arguments against the possibility of its ever being so developed that it will become a really scientific process; and yet the writer believes that the carburizing of steel, by the process of absorption, or, more technically speaking, the cementation process, may be followed with as much scientific accuracy as we find today in the application of any other process connected with the manufacture or treatment of that metal.

As long as manufacturers can not produce casehardening steel within narrower limits than present manufacturing specifications allow for the range of carbon and other chemical constituents of the metal, it can not be said that the manufacture of steel has been reduced to an exact science.

When those who carbonize, or otherwise, subject steel to thermal or thermochemical treatment are able to specify steel as "10 point" and get it 10 point instead of 10 to 20 point; or order "15 point" and get just that instead of 15 to 25 point; or when they order "20 point" they get what they order instead of 20 to 35 point, etc., both the manufacturer and the steel treater, and especially the carbonizer, may make some headway toward reducing their processes to an exact science.

The carbonizing process has no power to remove or to improve the imperfections, irregularities or other faults put into the steel during the process of manufacture; rather does it magnify or intensify them. If the variation of the carbon content is 10 points in the original steel it will be all of that in the carbonized product with an accompaniment of other variations of quality; if there is a wide variation in the content of other chemical constituents of the metal, they also will be reflected in the final results of carbonizing. It may not be by any increase of content of any element but carbon, but the uniform carbonizing and heat treatment of steel parts that vary in chemical analysis is sure to bring a corresponding variation in ultimate results.

As illustrating this the following tests, showing the effect of uniform treatment upon steels varying ten points, or more, in carbon content, are given. Analysis, before carbonizing was found to be:

	Carbon per cent	Silicon per cent	Sulphur per cent	Phosphorus per cent	Manganese per cent
Steel No. 1.....	0.21	0.005	0.041	0.025	0.43
Steel No. 2.....	0.11	0.005	0.034	0.010	0.45

Eight samples of each steel were subjected to identical carbonizing temperature and time and given the same subsequent heat treatments.

In the physical test every piece of the No. 2 steel, after carbonizing, showed up well for hardness, strength, and ductility after quenching at 1590 degrees Fahr. for the first quench, and 1425 degrees Fahr. for the second one. The pieces of No. 1 steel, when subjected to the same temperatures for quenching, were inferior in comparison; 25 per cent of them failed utterly because of brittleness, and none of the others were good enough to be considered usable.

*Consulting metallurgist, 4046 Jackson boulevard, Chicago. This is the first of a series of 10 articles on the "Carbonizing Process" written by Mr. Selleck.

The case of No. 2 showed a carbon content ranging from 0.90 to 0.97 per cent, while that of No. 1 ranged from 1.06 to 1.09 per cent. With the same carburizer, at the same time and under the same conditions, samples of another steel analyzing 0.24 per cent carbon, were carbonized and were given the same heat treatments as the above. They were, of course, a dead loss. The carbon content of the case on these samples ranged from 1.18 to 1.25 per cent.

That these samples, as well as the samples of No. 1 steel, might have proven satisfactory had the proper heat treatment been given them, is not doubted. The point to be considered is that if there is a range of 10 points in the steel parts before carbonizing there will be the same range after carbonizing and the same heat treatment will not do for the minimum and maximum of such a range. If we subject steel of 0.15-0.25 per cent carbon to what we are accustomed to call "an average normalizing temperature" of say 1550 degrees Fahr., we may have some of the parts perfectly treated so far as the "core" is concerned, and some of them may not show 50 per cent efficiency when subjected to physical tests.

The most common fault found with the carbonizing process is that it is unreliable; that a variety of results are obtained in a single operation; and that no part of the process is capable of standardization because of these faults. The tests mentioned above, at least partly explain the causes of these variations and indicate the truth of the claim made in opening paragraphs that the art of carbonizing can not be made a science until the art of manufacture has reached that stage. When the manufacturer can furnish for carbonizing a steel of a more definite analysis, within two points instead of 10 or 15, we may do something toward standardizing our process of carbonizing and reducing it to an exact science.

But until we understand in some measure what the carburizing process is, something about the nature of the action or reaction that occurs during the operation of the process we can not undertake intelligently its application. What, then, is the carbonizing process?

So far as present day knowledge of the phenomenon of carburization extends, the actual combination of carbon with iron by the cementation process seems not to be much more clearly and definitely known than it was at least three-quarters of a century ago. We are aware of its effects; we know by chemical analysis that the combination occurs, and by microscopical observation and physical tests we know of the structural changes produced in the metal because of such combination; but we do not fully understand the modus of the process of combination any more than we understand many other processes of the same natural laws that govern the process of carburization.

Our scientists and metallurgists have for many years been advancing various theories concerning the modus operandi of the carburization of iron, and if we follow their arguments and conclusions, we find ourselves lost in a theoretical fog; and our efforts to get to a sound practical basis of reasoning lead us around an endless circle.

For instance, in 1841, LePlay, a noted scientist of his day, advanced the theory of the carburization of steel, or "the diffusion of carbon into solid steel," as follows:

"The oxygen of the air, which surrounds the particles of wood charcoal, reacts with the carbon itself to form, first carbon dioxide (CO_2) then carbon monoxide (CO). The carbon monoxide would then yield to

the iron one-half of its carbon, again passing into carbon dioxide, and this would again be immediately reduced to carbon monoxide by the action of the carbon used as cement. In this way the cycles of reaction would continue indefinitely, and the carbon monoxide would act as a carrier, causing the penetration of the carbon into the solid metal."

While LePlay's theory is the one most generally accepted as correct, we find plenty of other metallurgists of his day and later, who dared to disagree with him, and put forth theories of their own in opposition to him; some of which may seem more comprehensible to the unlearned, practical operator of the process.

Marsden, another scientist, declared that the process of cementation was due entirely to the diffusion of the carbon, "in the form of an impalpable powder," into the steel "which, under the action of the high temperature was in an expanded and softened state"; while Ledebur declared that, "for the cementation of iron the intervention of gaseous carburizing compounds is in no wise necessary; * * * instead, the carbon can penetrate directly into the iron, and diffuse into it until it reaches a limit of saturation, depending upon the temperature."

Caron, another authority of the last century, said, "the compound which gives rise to the carburization of the iron can be none other than a volatile cyanide, capable of penetrating into the pores of the metal dilated by heat." He brought out a carburizing compound which has since been the basis of many of the modern commercial carburizers: Carbon, 3 parts; barium carbonate, 1 part." His theory of the action of this carburizer was that the barium carbonate, under high heat produced barium cyanide.

And so we find that many investigators of the phenomena of the carbonizing process, working for the most part along the same lines, have reached various conclusions concerning the actions and the reactions, that result in the carburization of iron through the application of the process of cementation.

The experiences and observations of the writer have resulted in a conviction that there is truth and merit in all the many theories, and that they are one and all but hints of the real truth concerning the process and its modus, that is not yet clearly understood.

Mannesmann, Marsden, and Ledebur, all practically agreed that the carburization of steel was accomplished through the molecular migration of solid carbon into the steel without the necessity of a gas being present, when the metal was highly expanded by heat.

Then LeChatelier came forward with the theory that "in the usual process of cementation nitrogen is the carrying agent of the carbon;" and we find that Fremy somewhat agreed with him in the declaration that "steel is, therefore, not a simple carbide, but a nitrogenized carburized iron." But, again, Professor Margueritte says regarding the subject of the nitro-carbide theory:

"The truth is that no one can prove today that steel is exclusively a nitro-carbide rather than a phospho-carbide, a chromo-carbide, a silico-carbide, a mangano-carbide, a titano-carbide, or a tungsto-carbide of iron." He took a sort of a middle ground, and declared that "iron combines with carbon, and is transformed into steel by contact * * * and also by the decomposition of carburetted gas; these two causes are present and act simultaneously in the cementation box."

And so far many years the controversy raged concerning the manner in which the carbon entered into the steel and there combined with the iron. The net result of all the investigation and discussion has been to establish LePlay's theory, practically as he stated it 80 years ago; but to the practical operator of the process, whose observations and practical experiences are his only technical training, a combination of all past theories more nearly fills the bill.

The most obvious result of all the above has been to prove beyond question the fact stated some centuries in advance of the authorities mentioned that: "when iron is packed in an earthen pot and surrounded with a mixture of old hoofs, horse dung, and pieces of hides, and is thoroughly sprinkled with the urine from a heifer, it will—after being baked for several hours at a good red heat—harden when quenched in water, equal to the best steel. To make it harder bake it longer."

In other words we have gained from it all a confirmation of the important fundamental fact that iron has such an affinity for carbon that it will absorb it from any carbonaceous matter with which it may be in contact when the physical condition of the two elements are in equilibrium.

It is a bit difficult for the uneducated operator of the process to understand that carbon can be dissolved in solid iron, when neither the iron nor the carbon are in a perfect fluid state; and the statement of Gullet that "the operation of cementation is really one of dissolving carbon in a solvent of iron" is not particularly enlightening to him when he knows that iron begins to dissolve or absorb carbon at 1472 degrees Fahr., according to Guillet, which is not sufficiently high to soften the metal enough for forging.

Roberts-Austen says "the diffusion of carbon into solid steel is a phenomenon entirely analogous to that of the diffusion of salt into water." But the the man, who has not studied the chemical phenomena of solid solutions, it seems a far cry from liquid water to solid steel.

Another analogy might be given that may be comprehended more easily. "The carbonizing of steel depends entirely upon the proper conditions being present when the steel is brought into contact with carbon; the principle of the process being based upon the well-known affinity the two elements have for each other. This affinity is limited only by their combining power, and the conditions of their contact." Here, then is the law under which the process operates—The Law of Affinities. We know very little about the law, in fact so little that some times we are in doubt about its existence; but it is hardly conceivable that rocks grow from pebbles; that pansies take on their myriad hues; that all that is beautiful as well as substantial in the material world about us is made so by the combinations of the various elements through their affinities for each other—that all this could be accomplished without the perfect working of a specific law governing every operation concerned in the development of these phenomena.

There is no difference between the processes involved in the absorption of water by a piece of dry wood and the absorption of carbon by iron. It is a question in both cases of the two materials being in the proper condition and in the proper relation to each other so that the laws governing their combination may operate.

To intelligently and successfully operate the carbonizing process it is essential that the operator should know how to establish the conditions

necessary for the accomplishment of the carburization of the metal according to the natural laws of absorption. These conditions being established, the process proceeds automatically, the results depending upon the period of time those conditions are maintained and the relation to each other of the following factors of the process.

There are four fundamental factors of the process, namely:

THE STEEL. Its nature and quality, as well as its physical condition. Steels of various chemical constitutions require varying thermal and thermochemical treatments. Steel when forged requires different treatment than when it is merely machined from the bar, and steel castings should have special treatment, according to their analysis and the service for which they are intended.

HEAT. The important factor of the process. It may well be termed the most important factor because upon the proper application of it depends the success of every operation. The metal can not absorb carbon until heat has established the proper condition in the iron; and the higher the temperature carried the more rapid will be the absorption of the carbon. Still there is a limit to the heating which must be observed if the best results are desired. Some steels require a higher temperature than others, but in all cases the velocity of penetration of carbon increases with the increase of temperature. These points will be discussed more fully later on.

CARBURIZER. It has been stated that iron will absorb carbon from carbonaceous matter of any sort if the proper conditions are established at the time of contact of the two. This is true, but iron has affinity also for other elements which exist in certain carbonaceous matter and which may be absorbed along with the carbon, thereby forming combinations not at all desired. Thus the carburizer should be chosen according to its freedom from all elements that might have a deleterious effect upon the steel.

TIME. This is the governing factor of the process. It bears a direct relation to temperature and is the gage of the operator for determining the depth of the penetration of carbon and, to some extent, the quality of the case.

The successful operation of the process depends upon the intelligence with which the operator is able to blend these four factors in his application of it.

Taking these four factors as a basis for the study of the process, we will consider them in the order named.

We must, first of all, understand the nature of the problem we have before us before we can intelligently begin its solution. If, for instance, we have a low carbon steel, approximately 0.15 per cent carbon, hot-rolled and simply machined from the bar, we have a different proposition to handle than we would have if we were called upon to treat the same carbon steel cold-rolled, or in the shape of forgings; and it will be advantageous to study the various conditions that the steel treater meets in a general case hardening business.

The steel generally used in parts that require case hardening is the type known as "S. A. E. 1020" and is of the following analysis:

Carbon	Manganese	Phosphorus (maximum)	Sulphur maximum)
per cent	per cent	per cent	per cent
0.15-0.25	0.30-0.60	0.045	0.05

The wide range of carbon permissible in this steel is at times the cause of irregularity of results, but it is undoubtedly the best all around type of steel for ordinary case hardened parts, where the demand is chiefly for a hard surface without much regard for strength. It is, however, in this type of steel that we find some of our hardest problems, because the same analysis is used for cold-rolled, and cold-drawn bars and tubes, that are frequently used in the manufacture of parts that require case hardening.

The difference in the action of the process upon hot-rolled steel and its action upon cold-rolled or cold-drawn steel, is that the velocity of penetration is much greater in the case of the hot-rolled, and there is a consequent difference in the chemical and physical condition of the case.

The Society of Automotive Engineers in specifying the carbonizing and heat treating temperatures for "1020" steel, makes no distinction between hot-rolled, cold-rolled, or cold-drawn steel, but every operator of the carbonizing process who is called upon to treat these various steels, all of the same analysis, knows there is a difference and often learn it to their sorrow and loss.

Because of the low temperatures at which cold-drawn, or cold-rolled steel gets its final passes at the mill, the structure of the surface is very dense and the temperature which would satisfactorily dilate a hot-rolled steel has very little effect upon the cold-rolled material. Even a higher temperature seems not to affect the velocity of penetration to the extent that would naturally be expected, and the only practical difference that can be suggested in the treatment specified by the S. A. E. seems to be additional time for the carbonizing period. This is not always a satisfactory solution of the trouble, as adding to the carbonizing time often has a bad effect upon the core.

The S. A. E. specified treatments for carbonizing "1020" steel are as follows:

"After forging or machining.

1. Carbonize at a temperature between 1600 and 1750 degrees Fahr. (1650-1700 degrees Fahr. desired.)
2. Cool slowly, or quench.
3. Reheat to 1450-1500 degrees Fahr. and quench."

This is "Treatment A" and is intended to be used where the development of a perfect core is not important. Where the conditions will permit, it is best to quench the parts direct from the pot as suggested, which will help somewhat in normalizing the core.

"Treatment B" is as follows:

1. Carbonize at a temperature between 1600 and 1750 degrees Fahr. (1650-1700 degrees Fahr. desired.)
2. Cool slowly in the carbonizing mixture.
3. Reheat to 1550 to 1625 degrees Fahr.
4. Quench.
5. Reheat to 1400 to 1450 degrees Fahr.
6. Quench.
7. Draw in hot oil at a temperature which may vary from 300 to 450 degrees Fahr., depending upon the degree of hardness desired."

It is noticed that there is a wide range of conditions allowable in the heat treatment of this particular type of steel, but with all the liberal in-

structions given, one important part of the program of treatment has been omitted. The specifications indicate that these treatments should follow the forging or machining, of the parts. No forged parts should ever be carbonized until they have been carefully annealed, after forging and before machining. Many failures in case hardening may be traced directly to the practice of carbonizing parts that have not been properly annealed after forging. In all forgings there are always certain strains set up in the metal, which, unless relieved by annealing, are apt to produce failures of various kinds and some times of the most unusual and unexpected nature that prove hard to explain. Annealing of forged parts, before carbonizing, should never be neglected.

In the use of cold-rolled steel of the above type the "B" treatment should always be given the parts after carbonizing, but more about the heat treatment of carbonized parts will be given later on.

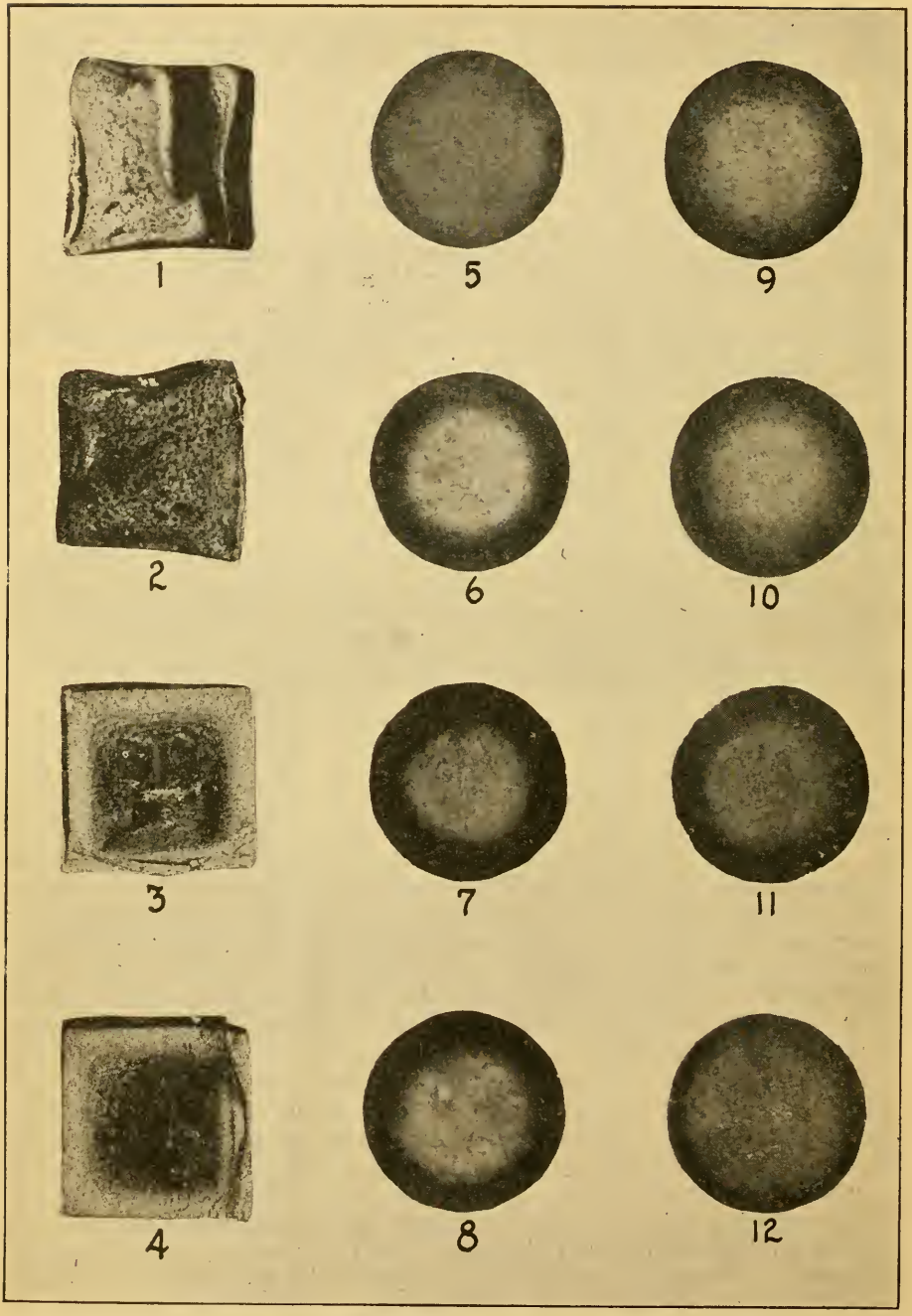
The specifications that have been given for the carbonizing of parts and their heat treatment, are presented merely to indicate that so far as scientific consideration has been given to the operation of the carbonizing process it has not been along the line of a close standardization of the thermal side of it. In the accompanying illustrations Figs. 1 and 2 show photographs of a sample of "1020" steel carbonized at a temperature of 1600 degrees Fahr. for a period of 6 hours; Figs. 3 and 4 are photographs of a sample of the same steel cut from the same bar and carbonized at 1750 degrees Fahr. for the same period of time. These temperatures are the minimum and maximum carbonizing temperatures allowed under the S. A. E. specifications and show clearly the range of penetration which may be obtained in following those specifications.

Figs. 13-15 illustrate the effect of a uniform carbonizing temperature upon three types of "1020" steel; that is Fig. 13 is a sample of hot-rolled steel, coming within the carbon specifications of "1020" steel, Fig. 14 is a sample of cold-rolled steel, and Fig. 15 is a sample of cold-drawn tubing. While these are not all of the same carbon content they are all within the wide carbon range of that steel. These samples were all carbonized in the same pot for a period of 12 hours at a temperature of 177 degrees Fahr. The difference in penetration is very marked, as the illustrations show, but in the etching of the samples it is not as marked as the fractures of the samples indicated. The actual penetration of Fig. 13 was three times that of Fig. 15 and twice that of Fig. 14. This bears out the claim made previously that the three types of steel in carbonizing must be considered as three distinct problems.

These examples are of importance as showing that heat, while it practically governs the velocity of penetration, is not the only element influencing it; and also as emphasizing the assertion previously made, that we should always know before beginning a carbonizing operation just what our problem is.

In concluding this consideration of the second factor of the process it may as well be understood that we have but touched upon a subject, about which volumes might be written—heat, its generation, application and control as applied to the carbonizing process—and more will be said upon the subject as we proceed with the discussion.

The third factor, the carburizer needs the most careful consideration because, as has been stated, from the carburizer it is possible for the iron to absorb elements that may be very injurious to the steel. For instance,



FIGS. 1 AND 2—SAMPLES OF "1020" STEEL AT 1600 DEGREES FAHR. FOR 6 HOURS. FIGS. 3 AND 4—SAMPLES OF THE SAME STEEL CARBONIZED AT 1750 DEGREES FAHR. FOR SAME LENGTH OF TIME. FIGS. 5 TO 12—THESE EXAMPLES ILLUSTRATE THE EFFECT OF VARIOUS CARBURIZERS ON STEEL UNDER UNIFORM CONDITIONS.

it would seem to be the height of folly to specify that sulphur should be kept very low in the original steel, below 0.05 per cent, and then surround it with a mixture of carburizing materials that would yield sufficient of that element to raise its content in the metal to a point that would make the steel useless. There are other elements that are equally pernicious in their effects which likewise may be found in impure carburizers, and so it is important that care be used in the choice of carburizing materials.

There are many angles to be considered in choosing carburizers. The manufacturers of them will inform the user that their particular carburizers are manufactured under formulas and processes that are scientifically correct and will perform the functions of the perfect carburizer under all conditions. But it is the opinion of the writer that no one carburizer will meet the requirements of all carburizing conditions, and that no one is so well able to know as the man who is called upon to use a carburizer under the conditions prevailing in his shop, which is the best for his particular purpose, providing, of course, that he knows enough about the process from experience to judge. It may be that a single type of carburizer may be successfully used on all kinds of work but the writer's experience has not given any proof of the fact.

The quality of work some times turned out by commercial case hardening plants, where but one grade of carburizer is used for all classes of work, is sufficient proof of the falsity of the claim that a carburizer that will do for parts that are very thin and do not require a carbon content above 0.80 to 0.85 per cent, will do also for parts that require a heavy penetration and a brinell hardness of 600 or higher.

When carburizers are so used, the hardness is usually governed by the subsequent heat treatment, which is a sort of an artificial method of producing something real.

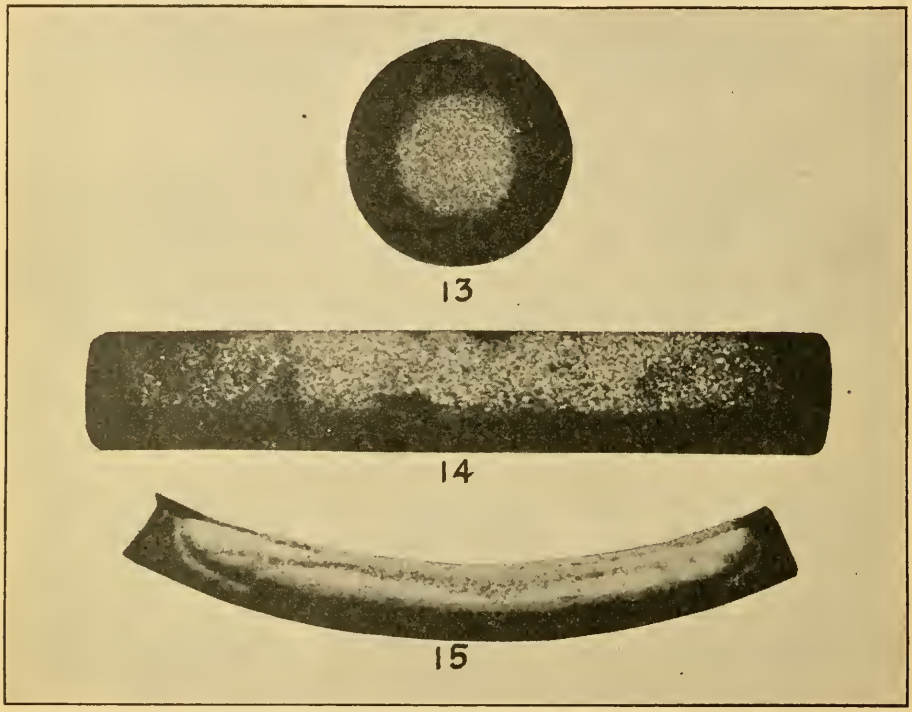
The highest grade of case hardening is accomplished only by the proper amount of carbon being added during the carbonizing period to meet the requirements of the case, followed by such heat treatment as will develop the best possible qualities of the carburized case, and the original steel in the core. In other words, it is better to have a case containing 0.80 per cent carbon and have it hardened at its maximum hardening temperature, than to have a case containing 0.90 per cent carbon and have it hardened at the minimum hardening temperature in order to have it meet the 0.80 per cent requirements. To harden steel at its maximum hardening temperature without passing its highest point of refinement, means to get the maximum efficiency in its wearing qualities; because, at that point the structure of the steel is at its best.

The function of the carburizer has been explained previously as being the source of the carbon with which the iron combines, either "through the decomposition of a carburetted gas" or through the molecular migration of carbon "in the form of an impalpable powder."

The consensus of modern opinion favors the former process as being responsible for the greater part of the action that results in carburization while the molecular progression theory is given but little credit, although there is much proof to be offered showing that it does play its part in all carbonizing operations.

But the gas theory being established, modern carburizers are compounded of materials that will produce the two gasses already mentioned, carbon monoxide and carbon dioxide and will set up and main-

tain those sequences of reactions mentioned by LePlay in his original thesis. The use of a pure carbon as a carburizer would be useless, because its action would be limited to the amount of oxygen contained in the small amount of air surrounding the carbon particles when it became heated to a carburizing temperature, since the evolution of monoxide is dependent first upon the evolution of dioxide. So in the manu-



FIGS. 13 TO 15—TYPICAL EFFECTS OF UNIFORM CARBONIZING TEMPERATURES UPON THREE TYPES OF "1020" STEEL. FIG. 13 IS A HOT-ROLLED STEEL BAR; FIG. 14, A COLD-ROLLED STEEL BAR; AND FIG. 15, A PIECE OF COLD-DRAWN TUBING. THE DIFFERENCE IN PENETRATION IS VERY PRONOUNCED.

facture of carburizers various materials are used in varying proportions as energizers or producers of carbon dioxide. It is the presence of these energizers that makes a carburizer quick or slow, according to their nature and their proportions in relation to the carbon base of the mixture. To an extent these energizers determine the carbon content of the case, and frequently they greatly influence the physical qualities of it, and for this reason the carburizer factor of the process should be the first to be standardized after the real standardization of case hardening steels has been accomplished.

How various carburizers affect steel under uniform conditions is shown by Figs. 5 to 12. At this time we can consider only what these photos show us of these samples—the difference in the depth of penetration, although there is much interesting data involved in the discussion of them, which will be taken up in a later paper. These samples were all carbonized in the same furnace at the same heat and for the same

period of time, but each sample was carbonized with a different carburizer.

Giolitti, in his *The Cementation of Iron and Steel,* says concerning carburizers "As for cementation proper, so for case hardening, the cements recommended by Reaumur, are fantastical mixtures of organic substances, such as the hoofs, hides, dung and urine of certain animals. But we have no right to be scandalized at this when we consider that many of the cementation mixtures still largely used today, and placed on the market under the strangest names are no less fanciful, nor do they give better results."

Of course Giolitti was speaking of conditions that obtained some years ago and our carburizer manufacturers have not been asleep; probably no branch of the manufacture of steel treaters supplies has had so much scientific study devoted to it as has the compounding of carburizers, especially during the period of the late war. Nevertheless it may be said that there are compounds on the market that are there chiefly because of their peculiar names, or because of claims that they are cheaper per cubic foot or per unit, or per something else and not because they are of any especially high quality, or merit.

Processes of manufacture are so hedged about by patents that the user of carburizers is compelled to choose between a limited number of compounds whether they are entirely satisfactory to him or not, unless he takes a chance and produces his own. By taking a chance is meant that unless proper mechanical equipment for mixing the various materials is used the mixture may not be uniform and unsatisfactory results follow its use.

Vegetable and animal carbons generally are used as carbon bases for carburizing compounds, with sometimes a small percentage of mineral carbon added; there are a few carburizers on the market, however, in which the carbon base is wholly mineral. Besides the carbon base a carburizer usually contains certain percentages of such energizing elements as barium carbonate, sodium carbonate, magnesium carbonate, calcium carbonate, and other carbonates and salts, which are usually proportioned according to the nature of the carbonaceous materials used in the carbon base, and the purpose for which the carburizer is to be used. Users of these materials have no way of judging their merit of efficiency except by actual tests made under standard conditions, which should always be done before a carburizer is adopted for regular use.

In many large plants, where metallurgical laboratories are maintained, tests are conducted and if the commercial carburizers available are not of the character best adapted to the work, the manufacturer is called upon to make a special mixture that will meet their requirements. This is done frequently, but only by the large users as it is unthinkable that every small user who thought he needed a special mixture could be accommodated. So it happens that the small user finds difficulty sometimes in getting just what he may need in the way of a carburizer, because he cannot go through a long line of tests of various mixtures, and there is no established standard of carburizers from which he can select one that will meet the demands of his particular work.

Carburizers should be compounded to produce certain definite results at certain temperatures upon steels of a definite analysis, and they may be so compounded. Where the demand for high class case hardening is

constant and steady, and the nature of the steel is known within close limits, the operator is not wise who does not fit his carburizer to his work, and if the manufacturer can not help him out, he is justified in working out his own material. The experiences of the writer with case hardeners, whose appreciation of the carburizer seems not to extend beyond the shape of its particles or its freedom from dust regardless of the other and more important qualities of it and who use one and the same carburizer for all manner of work under the most variable conditions, convinces him that this factor of the process needs more study, and its real nature and characteristics need to be better understood by the average operator of the process.

Economy must be considered, of course, in the selection of a carburizer, but that does not mean that the carburizer which contains the most cubic feet per ton is the most economical, even though its loss by use is less than those weighing much more per cubic foot; nor is it always the most economical carburizer that produces the greatest volume of carbon dioxide per pound of compound. The most economical carburizer is the one that meets every requirement of quality in the work it does without loss of parts because of more or less constant failures, at the minimum of cost for fuel, labor, wear and tear on equipment; and that will under these conditions show the lowest cost per cubic foot. The initial cost of the carburizer means nothing except as it is compared with its ultimate cost as indicated by the record of its performances in service.

The fourth factor of the process time is the gage of results. One of the very important parts of the process is the establishment of time schedules for the results desired. Time, bearing a definite relationship to temperature, it would seem not difficult to establish standard schedules if we knew just what that relationship was; but there is another factor to be considered—the carburizer.

We have seen that some carburizers act more rapidly than others at identical temperatures; that some produce high carbon cases while others produce lower carbon cases; so it is evident that the carburizer must be taken into consideration in the establishment of any schedule of time that we prepare. Herein we note again the weakness of the process because of the lack of any standardization of its factors; but, as a rule, the depth of case on ordinary case hardened parts is not important within several thousandths of an inch and, therefore, as long as there is sufficient depth to meet the requirements of the service to which the parts are to be subjected, a slight surplus usually is not any disadvantage. This does not apply to thin parts, or parts having light cross-sections; in such cases an excess of time in carburizing may entirely ruin the parts.

Someone, years ago, established a theory that "mild steel will absorb carbon at the rate of 1/16 inch in 8 hours, at a temperature of 1650 degrees Fahr.", but the same depth of penetration is often obtained in much less time, while in other cases a much slighter penetration is acquired in eight hours at that same temperature. While temperature and time bear a distinct relation to the depth of absorption of carbon, we have the nature of the steel to consider and the mechanical treatment it has received before being carbonized; only the use of good judgment on the part of the operator in applying time to his operations will insure satisfactory results. He must by observation learn the exact relation of time to temperature in the treatment of his own particular problems.

It is never advantageous nor economical to give a greater depth of case than the service of the parts will require; added depth means added time, and time is not only a measure of results but also a measure of cost. To all excess of time we must add excess fuel, excess labor, and excess wear and tear of equipment.

When we seek to apply the process, having attained some knowledge of the fundamental facts of its operation, our first problem is how to bring the four factors together into a working combination.

This is a large question, since again we have no standard equipment for this purpose but are obliged to follow methods of application that, from a scientific point of view, are very crude. They also are very ancient, for we still are in the "iron box age", although it is possible to obtain better containers than those made of cast iron. The difference is in the quality of the equipment rather than in any change in the methods of application. Alloy steels make a much better container than the old cast-iron ones, and from an economincal point of view they are in the end cheaper, but the initial cost is extremely high, and in many cases, prohibits their use.

Furnaces for carburizing are no different than those used for all other branches of steel treating, and choice of them rests upon their slight differences in mechanical construction.

In the use of such equipment as we have, there are a few rules that should be followed, carefully; for instance, in the use of containers of any sort the idea is not to use them as large as possible to conserve furnace space, or for any other reason. On the other hand they should be

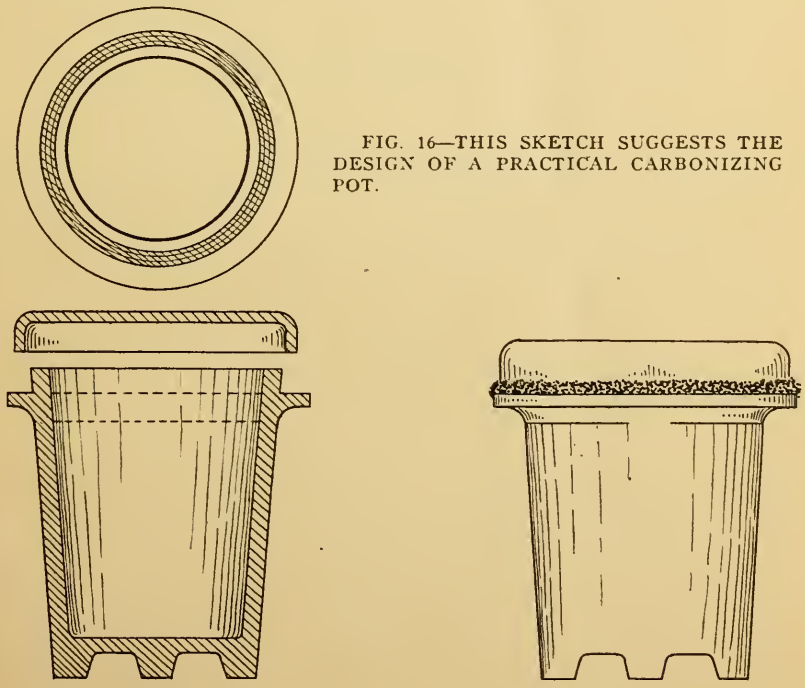


FIG. 16—THIS SKETCH SUGGESTS THE DESIGN OF A PRACTICAL CARBONIZING POT.

as small as possible and hold as few parts as economy will permit. It must be remembered that the heat, which is so important for the operation of the process, reaches the interior of the box or pot from the outside and must penetrate to the center of the box before there is uniformity of temperature in the steel parts. The time required for this transfusion of heat throughout the mass of material, depends largely upon the volume of steel in the pot. If it be too large or too compact, the travel of the heat toward the center will be so slow that uniformity of temperature may never be established; for if it is, the parts nearest the walls of the container will have had a carburizing temperature a much longer time than those in the center of the mass. From such practice results much of the irregularity of results. For this reason containers should be used that will give as rapid and as uniform heating throughout as it is possible to obtain.

All containers should be so designed that they can be tightly sealed; the covers should be made so that they will fit over the top and permit luting with fireclay below the top of the pot, so that the clay will not become mixed into the carburizer, as the presence of fire clay, scale from the boxes, and other foreign matter must be kept out of the carburizer if it is to be re-used. A suggestion for a practical carbonizing pot is shown in Fig. 16. Where the form of the parts will permit, round pots should be used, rather than square, or oblong, because in their use there is much less danger of placing the pots so close in the furnace that they will not heat uniformly. In placing the containers in the furnace sufficient space should always be allowed between them for the free circulation of the hot gases about them, and the round post facilitates such arrangement.

In designing pots or boxes for carbonizing it should be borne in mind than depth and length are not so objectionable in considering size, and capacity, as breadth is, thus a long narrow box will be more practical and satisfactory than a short wide one, where there is a chance for choice in the matter.

One other item of equipment must be considered and a very important one—the pyrometer. No case hardener should attempt the operation of the carbonizing process without the help of a reliable pyrometer, and if he is not experienced in the application of such instruments he should seek the help or advice of a competent pyrometer specialist in making his installation.

A pyrometer may be to an operator one of two things, a positive help in knowing the exact thermal conditions of his work at all times, or it may be a positive hindrance to him in knowing the exact conditions of his work at any time. It depends largely upon the manner of its installation and the care with which it is kept accurate in its readings by means of regular and accurate checking.

In selecting a pyrometer for the case hardening room ruggedness and simplicity should be considered as well as efficiency as a heat recorder. The pyrometer really is a simple instrument so far as its construction is concerned, since it has but three fundamental parts—the thermocouple, "the finger on the pulse"; the lead wires, "the nerves that carry the sensation of heat", and the recorder which in a human way acts as "the brain" of the system. The more simple these are in their construction the more practical they will be for the rough usage they are likely to get in the case hardening room.

When the pyrometer has been installed, if it be the best made, the most accurate and the most rugged, it is not to be considered as a substitute for the eternal vigilance of the men on the job.

Intelligence is the supreme factor of the carbonizing process and if it is lacking, all the other factors and the best equipment that can be secured will not produce satisfactory results.

These are a few of the fundamental factors of the process that should be known to the operator before he attempts its application, and are stated with the supposition that the process is to be applied to the treatment of such steels as are ordinarily used for case hardening. The treatment of other steels, such as alloy steels, will be considered in future articles, with a more intimate consideration of the factors.

It will not only be interesting but helpful for the operator to know how to judge the quality of his work from the observation of fractures, and also from microscopic examination, and micro-photographs, all of which will be included in our future study of the process.

INFORMATION DESIRED

One of the members of the Society submits a question for which he would appreciate suggestions from members who have had some experience with his difficulty. All answers submitted to the editor will be forwarded to the member very promptly.

"We have been experiencing difficulty in finding the proper material for plugging the center holes in tools before hardening in order to reduce cracking to a minimum. Different compounds tried out do not seem to stick in the holes and, therefore, I would welcome any suggestions as to good material to use for such work."

A CORRECTION

Through error the article entitled "A Discussion of Molybdenum Steels" appearing in the March issue of TRANSACTIONS was shown as written by Charles McKnight, president of the Carbon Steel Co., Pittsburgh. The author of this article was Charles McKnight Jr., works manager of the Carbon Steel Co.

NECESSARY PRECAUTIONS TO OBTAIN UNIFORMITY IN THE HEAT TREATMENT OF STEEL

By H. C. Loudenbeck*

(A Paper Presented by Title at Philadelphia Convention)

So much has been written regarding the heat treatment of steel that it seems futile to add to the literature on this subject unless the facts already accumulated can be presented in a new and original manner or new information can be obtained which will be useful to the art.

To obtain uniform results is one of the most difficult of the heat treater's problems, and to obtain these results certain precautions must be taken, which are often overlooked by the manufacturer. As a typical example, steel is purchased according to a specification that gives the desired physical properties when properly heat treated. The order is accepted by the steel mill and the steel manufactured and rolled accordingly. It is inspected by the purchaser's inspector who advises that it corresponds to the specification both chemically and physically and the shipment of the steel is authorized. After it is received by the purchaser and perhaps retested, and he is satisfied that the proper heat has been shipped, it is unloaded in the stock yard either in a pile by itself or unloaded on a pile supposed to be of the same specification.

It is afterward discovered that through some error in marking the steel, it has been mixed with a heat having a different composition. The whole lot, however, has been delivered to the forge shop and made into forgings which were delivered to the heat treating plant, the results of which are obvious: irregularity, rejections, and endless trouble by the user. This is only one of the many irregularities which may be found after the steel has been received by the purchaser. For example, the steel may not be properly labeled or tagged or the tags may become lost and uncertainty exists as to the particular quality of steel stored in the yard. Again, parts of bars from the forge shop are returned to the yard, stored with steel of different composition, afterward made into forgings, the supposition being that the lot of forgings are identical in composition.

From personal experience, the author is satisfied that great care should be used along these lines, especially as to the proper marking and storing of steel received in the forging yard. In these days, when so much attention is given to production and tonnage, the matter of quality often is overlooked and it requires constant supervision to see that the correct steel is used for the forgings intended.

If possible, each heat should be piled separately in the yard and correctly labeled with the heat number and specification number. When this particular lot is used for the forgings intended, this heat number should follow on the forging itself. If this requirement is too great for practical forging operations, heats of similar physical and chemical properties may be segregated and given a suitable code number representing the quality of steel. For example, a steel requiring 0.40 to 0.50 per cent carbon may be divided into two grades, namely, 0.40 to 0.45 per cent carbon and 0.46 to 0.50 per cent carbon. This will enable the forger to make less changes in marking dies and will also require fewer changes in heat treating.

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In a certain class of forgings it may be necessary to analyze each bar and grade accordingly. This has been found necessary for the manufacture of crankshafts for aircraft motors. In some cases, it may be necessary to make physical tests on each shaft from coupons attached thereto, the testing to be done before the shafts leave the heat treating department.

It has been found desirable to have someone connected with the metallurgical department in touch with the forging steel yard and supervise the marking and sampling of the steel as received from the mills. A man of this type is best qualified on account of his training and experience as he fully appreciates the importance of using a uniform steel of known composition in order to obtain uniform physical properties in the forgings made from that grade.

Another element which enters into the irregularity of heat treated forgings is the variation in the same heat of steel. For example, carbon and sulphur often vary considerably due to a segregated condition. Practically every heat varies more or less in this respect. Of course, this variation may be caused occasionally by mixed blooms of the mill but usually, it is due to segregation in the ingot which will cause a variation in the composition of the bars rolled from it. In other words, the blooms from the upper portion of the ingot will contain a higher percentage of carbon and sulphur than blooms from the lower portion of the ingot. It will be seen readily that bars rolled from these blooms will vary in proportion. A few examples on the variation of carbon in the same heat are illustrated as follows:

Size of Ingot Inches	Ingot No.	Heat No.	Carbon in Per cent Bottom of Ingot	Carbon in Per cent Top of Ingot
20 x 20	4	4323	0.46	0.48
	17		0.47	0.52
	4	6933	0.49	0.50
	12		0.46	0.50
	5	4325	0.53	0.63
	14		0.53	0.63
	3	6934	0.45	0.53
	1		0.45	0.51
	5	4333	0.54	0.61
	15		0.55	0.66
	3	4335	0.47	0.50
	10		0.44	0.51
	4	7437	0.44	0.48
	12		0.45	0.52

These are not exceptional heats. They were taken from the usual run of open-hearth practice. The ingots were cropped at the blooming mill until free of pipe as indicated by the shearing. This required from 20 to 35 per cent shearing. Samples were taken from the upper and lower bloom after the discard had been taken. It can be seen readily that bars rolled from the upper anl lower blooms would have practically the same composition as given above. The sulphur in these particular heats was quite low, running not over 0.035 per cent, usually in the neighborhood of 0.025 per cent and no great segregation was shown in this respect. It would be interesting to observe the effect of high sulphur, say 0.06 per cent in the ladle analysis in regard to segregation since many contend that sulphur running 0.06

per cent or slightly over does not have a detrimental effect on the physical properties of the steel. While this may be true, it should be considered that most specifications specify that the drilling should be taken half way between the center and outside of the bar. When this is done it does not represent the sulphur which may be in the center of the piece due to segregation.

Our experience has been that segregation is more liable to take place when the sulphur runs over 0.05 per cent than otherwise. It has been found that where the sampling is done according to the accepted method, a variation from 0.06 per cent, half way between the center and outside, to 0.12 per cent, when taken from the center of the bar, this steel will not make a desirable forging and will cause considerable irregularity during the heat treating process.

Irregularity in physical properties of forgings often is caused by variation in size and thickness of the forging at different portions and in some cases this is very difficult to control in order to have a uniform hardness throughout the piece. For example, an axle having a pad considerably thinner than the main body of the axle will refine and harden much stronger than the main portion. While this is overcome, to a certain extent, in the drawing operation, the final results will show considerable variation in the parts. It is difficult to overcome this and it often is necessary to draw the axle so that it will show a minimum hardness in the body in order to bring the hardness on the pad to the maximum. In other words, it means that a study must be made of the piece to be hardened before a definite program of hardening is accepted, thus it is a good plan to make tests on a few pieces.

By abnormal heats is meant heats of steel having the proper chemical composition but not having normal physical properties under regular heat treating. One particular heat which contained 0.36 per cent carbon and used for axle steel was difficult to refine with the ordinary process except in very small sections. Ordinarily no difficulty was found in hardening this steel to 250 brinell by quenching in cold water from a temperature of 1550 degrees Fahr. However, in this particular case the maximum hardness obtained was 185 brinnel. The analysis showed it to be normal with the exception that it contained more than traces of aluminum. The steel manufacturer may draw his own conclusion as to the finding of aluminum in steel but we cannot but think it had something to do with the difficulty in refining the steel.

In our experience, cold water should be used for quenching wherever possible as it has better penetration and gives more uniform results. It is often necessary to take certain precautions when water is used for quenching chrome nickel steel. The temperature of the water must be raised in some cases to about 110 to 120 degrees Fahr. and in the case of crankshafts, the time of quenching should be only a fraction of a minute, depending upon the size. After quenching they should be removed immediately to the drawing furnace. These precautions are necessary to prevent cracking.

The hardness of low carbon steels can be considerably raised by quenching in caustic soda solution. The strength of this solution should be 1 to 4. We have raised the hardness of a 0.20 per cent carbon steel from 185 to 300 brinell by means of this quenching medium. This was obtained on a section about 3 x 4 inches. It is necessary when using a solution of this sort to use a circulating system to keep the quenching medium cool.

Where oil is used it has been found that a grade of paraffine oil having a viscosity of 190 at 80 degrees Fahr. gives good results. This is improved by the addition of a small amount of fatty oil. The addition of 20 per cent refined whale oil gives excellent results.

This article is intended to throw out suggestions of a practical nature rather than a dissertation on the fine points of the art. Of course, it is understood that it is necessary to have the proper heat treating furnace, the proper temperature control, the proper time and manner of quenching, but unless the right grade of steel is provided for the purpose and steel of uniform quality, the results will be far from uniform.

THE RELATIVE ECONOMY OF ELECTRIC, OIL, GAS AND COAL-FIRED FURNACES

By T. F. Baily*

(A Paper Presented by Title at Philadelphia Convention)

Rapid elimination of natural gas as an industrial fuel and the rapid increase in the price of fuel oil, coupled with the statement of the United States Geological Survey that shortly it will not be available as an industrial heating medium, have brought the attention of the public generally to electric furnaces as one ultimate type of equipment that will combine not only accuracy of treatment to a degree which was never possible in fuel fired furnaces, but also reliability from the standpoint of supply of heat, as electricity has now become the most common of all commodities. It is true that there is a considerable thermal loss in the transformation of fuel to electric energy, nevertheless, the modern power plant is able to use the lowest grade of fuel; while the fuel used in industrial furnaces generally has been more expensive, as well as more difficult to obtain, as is evidenced by the gas and oil situation today.

From the standpoint of fuel conservation, is is of interest to note that even when taking into consideration the thermal efficiency of a modern power plant and distribution system of only 15 per cent, and an electric furnace efficiency of an average of 60 per cent, the net thermal efficiency for the entire cycle would be at least 9 per cent. On the other hand, assuming the same grade of fuel could be used conveniently in small industrial furnaces, which are now mostly fired by oil or gas, the efficiency probably would not run over 5 per cent, and probably it would require a higher grade of coal. Besides this, it would necessitate a modified design of furnace with a large combustion chamber. This would require a much larger floor space and would mean a complete new plant arrangement in most present installations. On the other hand, the electric furnace requires little more space than the present type of oil or gas-fired combustion furnace.

From a cost standpoint, it is difficult to make an accurate comparison, because of the wide variation in efficiency of the various fuel-fired furnaces; but taking as a basis, in the case of oil for heat treating operations, a consumption of 30 gallons of oil per ton of product, and with oil at 15c per gallon, which is the prevailing price at the present writing, the cost would be $4.50 per ton for fuel only.

With natural gas-fired furnaces, it is doubtful whether an efficiency of better than 6000 cubic feet of natural gas per ton of product can be maintained, and at a price of 50c per thousand cubic feet, the cost would be

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*President, Electric Furnace Co., Alliance, O.

$3 per ton for fuel only. An electric furnace of the same capacity, which is taken as 1000 pounds per hour, would consume not to exceed 300 kilowatt hours per ton of material heated, with an average fuel cost of 1¼c per kilowatt, which would bring the cost to $3.75 per ton for fuel only.

Thus it is to be noted that under average conditions on small sized units, which are the most common types found in the heat treating industry, there is not a great variation in fuel cost; and, after all, this is of minor consideration when compared with accuracy of treatment, in which field the electric furnace is pre-eminently fitted to produce the highest quality of material. This is especially true of the electric furnace when coupled with automatic control devices, either of the time element or pyrometer control type.

In the larger capacity furnaces handling several tons per hour, direct coal-fired or producer gas fired furnaces, which obtaining their gas from soft coal, show much better economies; but in similar capacities, electric furnaces also show better economies. When taking into consideration the recuperative car-type furnace, the current consumption will fall when annealing of larger tonnages of steel, to as low as 120 kilowatt hours per ton. Thus with current at 1c per kilowatt hour, the probable rate under such conditions, would be $1.20 per ton for fuel, as compared with coal-fired furnaces with coal at $4.80 per ton. This would mean that from a fuel standpoint alone the producer gas fired-furnace would have to have a consumption of not to exceed 500 pounds of coal per ton of metal heated. Besides, the difficulty of obtaining the desired grade of coal to operate well in the producers; the additional labor cost for handling both fuel and ashes from the producer; and the much larger space required for both the producer and gas-fired furnace are additional disadvantages.

From a labor standpoint the electric furnace requires the least attention. In some of the larger units used in heat treating, consisting of two furnaces and an automatic quench between, two men on the combined unit will handle as much as three tons of material per hour; while in nonautomatic plain hearth-type fuel-fired furnaces several times as many men would be required.

Still more important, it would be impossible to control in this hearth-type fuel-fired furnace, the heating cycle and the quenching conditions of the heat treating operation with anything like the accuracy obtained by the automatic electric equipment. In some operations, such as the annealing of high carbon high chromium steel, wherein a definite cooling cycle is required, the electric furnace offers substantially the only certain means of controlling this cooling cycle.

The comparison of the three types of furnaces may be briefly summed up in the statement that while no great difference exists in the actual fuel cost between the three, the electric furnace at the present time is the one that seems most certain of a continued and uninterrupted supply of fuel. In numerous cases the actual fuel cost may be higher with the electric furnace than by oil or gas; but for the accuracy of treatment and from a standpoint of cost per ton of material which actually meets the specified requirements, the electric furnace probably will be cheaper than any of the other types, and can be depended upon absolutely from a production standpoint.

News of the Chapters

TEN WAYS FOR CHAPTER BETTERMENT

The American Society of Mechanical Engineers contributed the following as methods of improving the chapter, its activities, as well as the members, themselves. We believe it valuable to our organization and therefore are reproducing it:

1. ATTEND THE MEETINGS. By so doing, you can make a definite contribution to the support of your chapter.
2. TAKE AN ACTIVE PART IN EVERY MEETING. Contribute in good fellowship, and in intelligent discussion of papers.
3. GET TO KNOW YOUR FELLOW MEMBERS. This is always possible before the Meetings; there is a special Committee appointed for the purpose.
4. MAKE YOURSELF TO KNOW THE MEN YOU HAVE ELECTED TO OFFICE IN THE CHAPTER. If there is work that you are willing to help in, let them know it.
5. BE A WORKING MEMBER. If asked to serve on Committees do it, and do it well.
6. DO YOUR PART IN INCREASING THE NUMBER OF MEMBERS. Both in the Society and the Chapter. One new member per year for each present member means 100 per cent growth.
7. BE A BOOSTER! REALIZE WHAT A. S. S. T. STANDS FOR IN THE LARGE, and let this attitude of mind be reflected wherever and whenever possible.
8. BEAR THIS IN MIND: Your officers and committee chairmen will welcome constructive criticism.
9. REMEMBER THIS IS YOUR CHAPTER. Yours to build up, or yours through apathy to let stagnate. In your own case, be a builder up.
10. YOU'RE NOT ONLY A STEEL ENGINEER; YOURS ARE THE RESPONSIBILITIES OF GOOD CITIZENSHIP. A. S. S. T. stands for the best ideals of both. Through the A. S. S. T. are the means for promoting both.

WASHINGTON CHAPTER

The Washington chapter of the Society had a very interesting meeting on March 18 at the Bureau of Standards. The speaker of the evening was Dr. G. K. Burgess, chief of the division of metallurgy of the Bureau of Standards, who presented a paper on the "Properties of Metals at High Temperatures, and Their Relation to Heat Treatment".

At a meeting of the chapter called in the ballroom of the Harrington hotel, the chapter was reorganized by the appointment of a nominating committee who presented before the chapter the following list of nominations:

Chairman—S. Tour, Ordnance Department.
Vice Chairman—W. L. Blankenship, Navy Department.

Secretary-Treasurer—H. J. French, Bureau of Standards.
Chairman Finance Committee—P. E. McKinney, Navy Dept.
Chairman Meetings Committee—H. E. Handy, Washington Steel & Ord. Co.
Chairman Membership Committee—H. J. French, Bureau of Standards.

These officers were unanimously elected. The chairman of each of the above committees was empowered to appoint the remaining members of his committee. Mr. Handy, chairman of the Meetings Committee, appointed Mr. Strauss of the Navy Department, and J. S. Vannick of the

H. J. FRENCH
Secretary-Treasurer, Washington Chapter

Ordnance Department as the other members of his committee. The Executive Committee is to consist of the three officers and the chairman of the Finance and Meetings Committees together with two additional members. Accordingly, S. B. Hunnings, metallurgist of the Washington Steel & Ordnance Company, and Dr. G. K. Burgess, of the Bureau of Standards, were elected members of the Executive Committee.

SYRACUSE CHAPTER

About 125 attended the meeting of the Syracuse chapter on Feb. 24, held in the Technology Club rooms, when A. H. d'Arcambal, chief metallurgist of Pratt & Whitney Co., Hartford, Conn., presented a paper on "High Speed Steel, Its History, Manufacture and Heat Treatment." This was one of the best meetings the local chapter has had, due to the fact that the discussion was very lively and also to the fact that Mr. d'Arcambal was master of his subject. His entertaining personality assisted him materially in getting a splendid hearing for his paper.

A joint meeting of the Syracuse sections of the American Society for Steel Treating, and the American Chemical Society was held on Friday evening, March 4, at the Chamber of Commerce rooms. Over 200 members gathered to hear Dr. John A. Mathews, president of the Crucible Steel Company of America, Pittsburgh. Dr. Mathews spoke upon "Crucible Steel Products and Their Application", and paid particular attention to the advances made in the steel industries in the local mills.

DETROIT CHAPTER

The March meeting of the Detroit chapter was held on March 14 at the Board of Commerce rooms, and was addressed by A. D. Freydendahl, engineer of the Chicago Flexible Shaft Co., upon the subject of "Principles of Combustion as Applied to Industrial Furnaces." About 100 were in attendance at this meeting which proved to be one of the most successful the chapter has had.

ROCHESTER CHAPTER

About 50 attended an informal discussion on the "Hump Method of Heat Treating", at the Camera Works, on March 4. Many interesting points were brought up for discussion and the evening proved very instructive.

CHARLESTON CHAPTER

The March meeting of the Charleston chapter was held on March 1 at the Kanawha hotel, when D. M. Giltinan spoke on "The Metallurgy of High Speed Steel". Some 65 members were in attendance, and the paper which was well given, was heartily received. A general discussion followed, lasting more than hour.

HARTORD CHAPTER

The February meeting of the Hartford chapter was held in the Chamber of Commerce rooms on Feb. 24, when James A. Baldwin presented a paper on "Wrought Iron." A very good discussion followed the presentation of the paper.

The March meeting was held in the Chamber of Commerce rooms on March 10 and attended by about 65 members and guests. The main paper of the evening was presented by A. P. R. Wadlund, of the Henry Souther Engineering Co., on "The Bessemer Process." The subject of chromium was also discussed, and a paper presented on the "Nomenclature of Hardening Terms." The discussion was very interesting.

PHILADELPHIA CHAPTER

The Philadelphia chapter held its regular meeting on March 25 in the auditorium of the Engineers Club. W. L. Patterson, director of technical research, Bausch & Lomb Optical Co., presented an illustrated lecture on "The Optics of Metallography". The meeting was well attended and the discussion was lively and instructive.

TOLEDO CHAPTER

C. M. Brown, vice president of the Colonial Steel Co., Pittsburgh, spoke before the members of the Toledo chapter on "Standardization of Tool Steel". The meeting was held in the rooms of the Commerce Club on March 10. Previous to the meeting a dinner was served in Kests' restaurant. Mr. Brown has made a very careful study of the standardization of tool steel, and his paper was consequently of much interest to those in attendance.

PITTSBURGH CHAPTER

The March meeting of the Pittsburgh chapter was held March 15 at the Chatham hotel, and was addressed by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering,* who spoke on "What is New in Metallurgy". Mr. Thum handled his subject in a very able manner, speaking also of the lines upon which development in future might be expected.

MILWAUKEE CHAPTER

The Milwaukee chapter had a very interesting meeting at the Hotel Medford on Feb. 23 which was addressed by E. E. Thum, associate editor of *Chemical and Metallurgical Engineering.* The meeting was attended by a large number, and was preceded by a dinner at the Hotel Medford.

SPRINGFIELD CHAPTER

The March meeting of the Springfield chapter was held on March 18 in the Chamber of Commerce building, when Hannibal A. Kunitz, engineer of the Advance Furnace & Engineering Co., presented a paper on "Automatic and Special Continuous Furnaces". Mr. Kunitz was well qualified to speak on this subject because of his wide experience with the design and construction of furnaces. The discussion following was one of the best that has been held for some time and was very lively and evidenced appreciation of the value of the talk.

NEW YORK CHAPTER

About 60 members were in attendance at a meeting of the New York chapter held at the Machinery Club. The lecture of the evening was by J. A. Brown, vice president of the W. S. Rockwell Co., on "Factors Governing Production of Heated Products". The meeting was preceded by a dinner at the Engineers Club.

CLEVELAND CHAPTER

One of the most enjoyable meetings the Cleveland chapter has held for some time was when they took advantage of the presence of a number of well known men who were in Cleveland to attend a meeting of the National Nominating Committee, on Friday, March 25. The Nominating Committee was invited to remain over, and furnish the basis of the program for the meeting, and they spoke on the following subjects:

J. Fletcher Harper, assistant superintendent, Allis Chalmers Mfg. Co., Milwaukee, Subject: "Effects of Deep Etching".

Major A. E. Bellis, metallurgist, U. S. Armory, Springfield, Mass. Subject: "Quenching of High Speed Steel".

A. W. F. Green, chief of laboratory, John Illingsworth Steel Co., Philadelphia Subject: "Things to Be Done".

C. U. Scott president, C. U. Scott Co., Rock Island, Ill. Subject: "Critical Points. Who Discovered Them? What are they?"

Quite a diversity of subjects was brought up for discussion, and it proved to be one of the most interesting meetings the chapter has ever held. The dinner was served at 6:30 and was well attended.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

AURELL, Carl (M-2), Billings & Spencer Co., Hartford, Conn.
BACKUS, Harold A. (M-3), care Gallaudel Aircraft Corp, E. Greenwich, R. I.
BARNES, Cyrus (M-1), 201 Devonshire St., Boston, Mass.
BEEARS, Byron (M-3), 401 "N" St., Reading, Pa.
BIHL, Wm. (M-3), Iron Mountain Co., 927 W. 95th St., Chicago, Ill.
BORNSTEIN, Hyman (M-12), 636 10th St., Moline, Ill.
BRAYTON, H. M. (M-2), Frankford Arsenal, Philadelphia, Pa.
CARABIN, M. A., (Sb-1) Detroit Edison Co., 2000 Second Ave., Detroit, Mich.
CARUTHERS, M. W. (M-3), 439 Franklin Ave., Wilkinsburg, Pa.
COLBUS, H. H. (M-2), Halcomb Steel Co., 633 Arch St., Philadelphia, Pa.
COOPER, Ransom (M-3), Sanderson Wks., Crucible Steel Co. of Amer., Syracuse, N. Y.
DAVIS, G. F. (M-3), 2 Hubbard Court, Charleston, W. Va.
DENISON, Winthrop W., (M-3) 300 Walnut Place, Syracuse, N. Y.
DRISCOLL, J. J., (M-3) Sanderson Wks., Crucible Steel Co. of A., Syracuse, N. Y.
DUFFY, G. F. (M-1), 76 Lawrence St., Waltham, Mass.
EDGETT, H. J. (M-1), 52 Greenwood Ave., Greenwood, Mass.
EXNER, W. F. (M-12), Manche Storage Battery Co., 190 Kingshighway, St. Louis, Mo.
FAY, H. H. (M-12), 523 S. Columbia St., South Bend, Ind.
FULTON, L. M. (M-3), 3208 Carroll Ave., Chicago, Ill.
GAMBLE, D. E. (M-3), 6341 Ingleside Ave., Chicago, Ill.
GIBSON, L. H. (M-1), 3 Fordham St., Jamaica Plain, Mass.
HEATH, Leslie C. (M-1), Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
HIGGINS, J. J. (M-1), 12 Fern St., Pittsfield, Mass.
HOLSBERG, W. A. (A-12), 112 Clybourn St., Milwaukee, Wis.
JACOBSON, Theodore (M-3), S. K. F. Ball Bearing Co., Hartford, Conn.
JARDINE, James J. (M-3), care Y. M. C. A., Syracuse, N. Y.
JENKINS, Geo. W. (M-1), 1413 W. York St., Philadelphia, Pa.
JOHNSON, James A (M-3), 1445 Baker, Detroit, Mich.
JOSEPH, Carl F. (M-1), 4845 Concord, Detroit, Mich.
KING, B. F., Frost Gear & Forge Co., Jackson, Mich.
KONOLD, Geo. F. (M-3), Warren Tool & Forge Co., Warren, Ohio.
KOONZ, John F. (M-1), 3306 "H" St., Philadelphia, Pa.
LARDNER, James K. Jr. (M-9), 723 20th St., Rock Island, Ill.
LIZOU, Leo (M-12), 1372 Richard St., Milwaukee, Wis.
MAAGE, A. E. (M-12), 718 34th St., Milwaukee, Wis.
MAHONEY, J. D. (M-1), 58 Hamilton St., Dorchester, Mass.
MATHEWS, J. R. (A-3), 205 Kresge Bldg., Detroit, Mich.
MATTISON, H. H. (M-3), Sanderson Wks., Crucible Steel Co. of Amer., Syracuse, N. Y.
MILLER, Chas. H. (M-1), McIntosh & Seymour, Auburn, N. Y.
MOORE, C. D. (A-3), 1331 St. Clair Ave., Cleveland, O.
MORLEY, L. Morton, (M-11), care Brown Instrument Co., Wayne Junction, Philadelphia, Pa.
NEWKIRK, E. D. (M-3), Onondaga Steel Co., Syracuse, N. Y.

NEWSTROM, J. V. (M-3), Iron Mountain Co., 927 W. 95th St., Chicago, Ill.
NIEHAUS, A. D. (A-1), care Crucible Steel Co., 1518 N. 9th St., St. Louis, Mo.
PARKER, Heber (M-12), Studebaker Corporation, South Bend, Ind.
PENHOLE, W. S. (M-3), 1509 Washington St., Charleston, W. Va.
PFEIFER, Carl B. (A-3), 1723 Lafayette Blvd., Detroit, Mich.
POTTS, Chas. W. (S-3), care Horace T. Potts & Co., Philadelphia, Pa.
REED, B. F. (A-12), 684 Cramer St., Milwaukee, Wis.
RICKABAUGH H. H. (M-11), 809 Eighth Ave., Altoona, Pa.
RIDER, Fred H. (M-2), 112 N. Cedar St., Massillon, Ohio.
ROWE, Chas. O. (M-1), care Electric Alloy Steel Co., 511 Penn. Bldg., Philadelphia, Pa.
SAYRE, Mortimer F. (M-12), Union College, Schenectady, N. Y.
SEIDELL, Arthur J. (M-12), St. Louis Paper Case & Tube Co., 4400 Union Ave., St. Louis, Mo.
SHERMAN, P. B. Jr. (M-1), 2108 E. 96th St., Cleveland, O.
SHERWOOD, R. A. (M-3), Halcomb Steel Co., Syracuse, N. Y.
SMITH, Robt. F. (A-3), 413 Seitz Bldg., Syracuse, N. Y.
SMITHIES, M. W. (M-3), care Atlas Ball Co., 4th & Glenwood St., Philadelphia, Pa.
SQUIRE, Thos. S. (M-12) 144 Lascellus St., Syracuse, N. Y.
STARY, Lawrence G. (J-2), 3159 E. 90th St., Cleveland, O.
STOECKLE, Chas. H. (M-12), 2114 N. 19th St., Philadelphia, Pa.
SYKES, W. P. (M-1), 1770 E. 45th St., Cleveland, O.
THOMAS, C. H. (M-3), 499 Ridgewood Ave., Glen Ellyn, Ill.
THUR, Jos. H. (M-1), 3329 N. 18th St., Philadelphia, Pa.
WEST, Hubbell B. (M-3), Halcomb Steel Co., Syracuse, N. Y.
WHONNHART, Lewis, (M-3) Sanderson Works, Crucible Steel Co. of America, Syracuse, N. Y.
YOUNG, Harry M. (M-1), Western Wire Products Co., 3rd & Spruce St., St. Louis, Mo.
ZIMMERLI, F. P. (M-1), Solvay Process Co., Detroit, Mich.

CHANGES OF ADDRESS

ACKERMAN, A. H.—from 2230 Leland Ave., Chicago, Ill., to 427 Reaper Building, 105 N. Clark Street, Chicago, Ill.
ARTHUR, Alec C.—from 1845 Jones Street, Indianapolis, Ind., to 1916 Jones Street, Indianapolis, Ind.
BAKER, F. C.—from Wilson Maeulin Co., 306 Monroe Bldg., Chicago, Ill., to 163 W. Washington St., Chicago, Ill.
BEEMAN, E. P.—from 137 Beals Ave., Detroit, Mich., to 475 Baltimore, West, Detroit, Mich.
BEGG, Thomas K.—from Wm. E. Baulieu, Bridgeport Brass Co., Bridgeport, Conn., to Thomas K. Begg, Bridgeport Brass Co., Bridgeport, Conn.
BIRMINGHAM, T. F.—from 1160 Morraine Street, East Chicago, Ind., to 1160 Morraine Street, Hammond, Ind.
BLACK, J. W.—from 159 Oak Grove Ave., Springfield, Mass., to 28 Dayton St., New Haven, Conn.
BOOTH, E. C.—from 2342 Park Ave., Indianapolis, Ind., to 223 W. 5th St., Peru, Ind.
BROWN, N. E.—from U. S. Electrical Mfg. Co., 300 S. Central Ave., Los Angeles, Cal., to Box 155, Los Angeles, Cal.

BURK, Edward J.—from 1210 Sturm St., Indianapolis, Ind., to 333 Walcott St., Indianapolis, Ind.

COPELAND, Alexander W.—from Det. Gear & Machine Co., 127 Franklin St., Detroit, Mich., to 670 E. Woodbridge St., Detroit, Mich.

COPELAND, C. W.—from Locomobile Co., Bridgeport, Conn., to Timken Roller Bearing Co., Detroit, Mich.

CRESSMAN, H. E.—from E. F. Houghton & Co., 511 Gwylm Building, Cincinnati, Ohio, to 131 W. Woodbridge Street, Detroit, Mich.

CROWE, Victor—from 620 Central Ave., Dunkirk, N. Y., to 19 Chant St., Fredonia, N. Y.

DALE, F. M.—from Rochester Steel Treat Co., 108 Platt St., Rochester, N. Y., to Rochester Steel Treat. Co., 15 Caledonia Ave., Rochester, N. Y.

DALGAARD, Aeil—from Camillus, New York, to 60 Marcellus St., Camillus, New York.

DAUNCEY, Wm. Geo.—from 50 Park Ave., Montreal, Can., to Cascade Inn., Shawinigan Falls, P. Q., Can.

DAVIS, Frank G.—from 302 East Woodbridge St., Detroit, Mich., to 1437 Franklin St., East, Detroit, Mich.

DORCHESTER, Paul—from Surface Comb Co., 366 Gerard Ave., Bronx, New York City, to 173 Sylvan Ave., Leonia, New Jersey.

DOWIE, H. E.—from Ward Tool & Forging Co., Latrobe, Pa., to 439 Ohio Ave., Wilson, Pa.

DRAKE, Frank B.—from care Johnson Gear Co., 735 Folsom St., San Francisco, Cal., to 8th & Parker, Berkeley, Cal.

EDWARDS, Wm. A.—from Ludlum Steel Co., 33 Woodward Ave., Detroit, Mich., to 1776 W. Lafayette Boulevard, Detroit, Mich.

ENGLEHART, R. J.—from 182 Mansfield St., New Haven, Conn., to P. O. Box 148, Yale Station, New Haven, Conn.

EVANS, H. J.—from 201 Western Ave., Aspinwall, Pa., to New Kensington, Pa.

FAIRFIELD, J. A.—from 1650 Lincoln Ave., Lakewood, Ohio, to care Eaton Electric Furnace Co., Taunton, Mass.

FAY, H. H.—from 502 S. Franklin Ave., South Bend, Ind., to 523 S. Columbia St., South Bend, Ind.

FOSTER, O. A.—from 811 Lakewood Ave., Detroit Ave., Detroit, Mich., to 133 Ferris St., Detroit, Mich.

FULLMORE, H. W.—from 1574 Quarrier Ct., South Charleston, W. Va., to 23 Curry Street, South Charleston, W. Va.

GOSSETT, E. J.—from care Bell & Gossett, 609 W. 30th St., Chicago, Ill., to 117 N. Dearborn St., Chicago, Ill.

GOWING, W. A.—from 30 Adelaide St., Detroit, Mich., to 66 Adelaide St., Detroit, Mich.

GRAY, R. T.—from 38 S. Dearborn St., Chicago, Ill., to 616 S. Michigan Ave., Chicago, Ill.

GREINER, R. C.—from U. S. Tractor & Machy. Co., Menasha, Wis., to 3411 Grand Ave., Minneapolis, Minn.

GUISWITE, R. D.—from 1533 N. Alabama St., Indianapolis, Ind., to 418 15th Apt. 42, Indianapolis, Ind.

HANDY, James O.—from Pittsburgh Testing Lab., 906 Bedford Ave., Pittsburgh, Pa., to Pittsburgh Testing Lab., P. O. Box 1115, Pittsburgh, Pa.

HEDIN, Oscar C.—from 412 S. 6th St., Minneapolis, Minn., to No. 100 First St., N. Minneapolis, Minn.

HILL, Jas. B.—from 303 Peoples Bank, Moline, Ill., to 512 Peoples Bank Bldg., Moline, Ill.

HITTLE, J. A.—from 1141 Laurel St., Indianapolis, Ind., to 4119 Broadway, Indianapolis, Ind.

HOLLANDER, J. A.—from 545 Enright Ave., Cincinnati, Ohio, to 2159 Lawn Ave., Norwood Station, Cincinnati, Ohio.

HOLLERITH, C. B.—from 2063 N. Meridian St., Indianapolis, Ind., to 3515 N. Penn Apt., Indianapolis, Ind.

HULBERT, L. G.—from care Mercer Motors Co., Trenton, N. J., to Hare's Motors, Inc., Bridgeport, Conn.

HUMPHREYVILLE, L.—from 1666 E. 32nd St., Cleveland, Ohio, to 480 E. 112th St., Cleveland, Ohio.

IRONSIDE SON & CO. (J. W. ROSE)—from 40 Muncing Lane, E. C. 3, London, England, to 39 Grosvenoi Place, London, England, S. W. I.

JACKSON, G. H.—from care National Steel Co., 111 W. Washington St., Chicago, Ill., to 2240 Washington Ave., Racine, Wis.

JOHNSON, Walter—from 301 Kentucky Ave., Indianapolis, Ind., to Singleton & Belt Ry., Indianapolis, Ind.

KELLOGG, W. O.—from General Combustion Co., 308 E. 42nd St., New York City, to 39 Cortlandt St., Suite 1013, New York City.

KLEIBER, Paul—from 60 N. Bolton St., Indianapolis, Ind., to 316 N. State St., Indianapolis, Ind.

KRETZSCHMAR, A. W.—from 142 Chene St., Detroit, Mich., to 600 Chase St., Detroit, Mich.

LANZ, Clarence—from 216 Irving St., Toledo, Ohio, to 2611 Albion St., Toledo, O.

LEARMOUTH, W. J.—from 268 Dexter Blvd., Detroit, Mich., to 8340 Dexter Blvd., Detroit, Mich.

LEVIN, Joseph—from 16 Margery Rd., Welland, Ont., Can., to 1933 Forbes St., Pittsburgh, Pa.

LILLY, Geo. C.—from 606 W. Market St., Bethlehem, Pa., to 707 W. Market St., Bethlehem, Pa.

MARLOWE, J. S.—from 204 Lombard Bldg., Indianapolis, Ind., to 536 Bankers Trust Bldg., Indianapolis, Ind.

MATHEWS, John A.—from Crucible Steel Co. of Amer., Pittsburgh, Pa., to 17 E. 42nd St., New York City, care P. O. Box 11, Grand Central Sta.

MILNOV, Edw. L.—from Ludlum Steel Co., Real Estate Trust Bldg., Philadelphia, Pa., to Ludlum Steel Co., Watervliet, N. Y.

MULL, H. C.—from 1540 McCormick Bldg., Chicago, Ill., to 122 S. Michigan Ave., Chicago, Ill.

NIGHTINGALE, G. V.—from Wilson Maeulin Co., 104 S. Michigan Ave., Chicago, Ill., to 163 W. Washington St., Chicago, Ill.

NISBET, Geo. B.—from Brier Hill Steel Co., Youngstown, Ohio, to Erie Smelting & Iron Co., Erie, Pa.

McINTYRE, F. J.—from 131 Center St., Jackson, Mich., to G. D. Bay City, Mich.

McKEAN, H. C.—from 1405 E. 89th St., Cleveland, Ohio, to 12440 Cedar Rd., Suite 4, Cleveland, Ohio.

OLCOAT, Frank—from 53 Cottage Place, New Britain, Conn., to 125 Smalley St., New Britain, Conn.

ORNE, C. O.—from Page Needle Co., Springfield, Mass., to 76 Hudson St., Somerville, Mass.

PIERCE, E. J.—from Columbia Graphophone Mfg. Co., Bridgeport, Conn., to Lewis Eng. Co., 25 Church St., New York City.

PLOURD, Wm. H.—from Simonds Mfg. Co., Brookfield, Ill., to 2911 Park Ave., Chicago, Ill.

PORTERFIELD, C. D.—from 29 W. 31st St., New York City, to 287 Willard Ave., West New Brighton, N. Y.

ROBERTS, E. H.—from John Obenderger Forge Co., Milwaukee, Wis., to 3209 Wells St., Milwaukee, Wis.

ROBINSON, J. W.—from Park Chem. Co., 29 Lovett St., Detroit, Mich., to 1305 Seventh St., Port Huron, Mich.

ROCK, Frank W.—from 166 Bunnell St., Bridgeport, Conn., to 43 Plymouth Court, Milford, Conn.

ROSEN, Joe—from care Lmograph Co., Davenport, Iowa, to Rock Island, Ill.

RUNECKOFF, L.—from 2741 28th Ave. S., Minneapolis, Minn., to East Rt. No. 1, Box 26, Minneapolis, Minn.

SCHEUING, Fred—from 311 W. 26th St., New York City, to 2328 Richmond Terrace, Port Richmond, Staten Island, N. Y.

SCHRAMM, Otto—from 339 Bryant Ave., Syracuse, N. Y., to Homeside Steel Treating Co., Fourth St., Detroit, Mich.

SCHRIEBER, F. C.—from 1433 Sherwin Ave., Chicago, Ill., to 1433 Sherwin Ave., Evanston, Ill.

STACKS, D. H.—from Whitney Mfg. Co., Hartford, Conn., to 1558 Boulevard, West Hartford, Conn.

STANTON, R. F. V.—from 42 Collins St., Hartford, Conn., to 282 Laurel St., Hartford, Conn.

TERRY, T. B.—from 15 West First St., Dayton, Ohio, to 19 Richmond St., Dayton, Ohio.

WADLUND, A. P. R.—from 108 Prospect Ave., Hartford, Conn., to 319 New Park Ave., Hartford, Conn.

VANTASSEL, W. N.—from 275 Cooke St., Waterbury, Conn., to 206 Plaza Ave., Waterbury, Conn.

WEBB, G. A.—from 52 Ravenwood Ave., Detroit, Mich., to 105 Manistique Ave., Detroit, Mich.

WELCH, S. N.—from P. O. Box 1318, Providence, R. I., to 23 Sabine St., Providence, R. I.

WILLIAMS, J. H. G.—from Henry Souther Engr. Co. 11 Laurel St., Hartford, Conn., to care Billings & Spencer, Hartford, Conn.

WILLIAMS, R. H.—from care Messrs. Sidney Williams & Co., Sydney, N. S. W., Australia, to Constitution Rd., Dulwich Hill, Sydney, Aust.

ZILKY, Louis C.—from R. F. D., South Bend, Ind., to 626 E. Haney St., South Bend, Ind.

MAIL RETURNED

Any member knowing the present address of those listed under "Mail Returned" will confer a favor on the Society by sending the correct address to 4600 Prospect Ave., Cleveland, Ohio.

BARRE, Louis, Route 2, Gilletts Lake, Jackson, Mich.
HARING, Arthur W., 214 Newbury St., Boston Mass.
HARTLEY, E. S., 340 S. Pacific Ave., Pittsburgh, Pa.
KIEFER, A. E., 650 Beaconsfield, Detroit, Mich.
POWELL Geo. R., 605 Munsey Bldg., Baltimore, Md.
SUBBERRA, A. W., 625 Hamilton Ave., Detroit, Mich.
THOMPSON, P. E., Steel Sales Co., Jefferson & Adams St., Chicago, Ill.
WEIDNER, Robt., 217 S. Flower St., Los Angeles Cal.

Commercial Items of Interest

"Form Value of Energy in Relation to Its Production, Transportation and Application," a paper prepared by Chester C. Gilbert, consulting engineer, Arthur D. Little, Inc., Washington, and Joseph E. Pogue, industrial economist and engineer, Sinclair Consolidated Oil Corp., New York, and presented before the fuels section, annual meeting of the American Society of Mechanical Engineers, New York, Dec. 7-10, 1920, has been reproduced in bulletin form by the W. S. Rockwell Co., 50 Church street, New York. This paper discusses some fundamental factors governing the utilization of fuel resources. Two charts are included in the bulletin.

In the January-February, 1921 issue of *Metal Heating*, a journal devoted to the interests of heat treaters and forgers and published by the Tate-Jones & Co., Inc., Pittsburgh, are reprinted three articles recently published in TRANSACTIONS. The articles and their authors are as follows: "Steel for Machine Parts," by Robert M. Taylor, works engineer, the American Tool Works Co., Cincinnati; "Microconstituents in One Section of a Metcalf Test Bar," by Oscar E. Harder, associate professor of metallurgy, University of Minnesota; and "Heat Treatment of Automobile Springs," by Harry E. Hemstreet, general foreman, Sheldon Spring & Axle Co., Wilkes-Barre, Pa. The fourth article appearing in the publication is entitled "The Rotary or Rotating Hearth Furnace" and describes a furnace manufactured by the Tate-Jones & Co.

Land has been purchased by Horace T. Potts & Co., Philadelphia, containing about 10 acres at the corner of D street and East Erie avenue. This land, it is stated by the company, will be used as a site for a modern plant building later. It is estimated the investment will involve $500,000.

The American Gas Furnace Co. has concentrated its entire personnel at its main office at Elizabeth, N. J., where its two plants are located. It has discontinued selling through its former sole agents, E. P. Reichhelm & Co., Inc. These changes are part of a plan to place the entire organization of the company, more fully at the disposal of its customers.

To provide additional working capital for the development of its spring business, the capital stock of the Garden City Spring Works, 2300 Archer avenue, Chicago, recently was increased to $500,000. The company has become the sole licensees under the Dilley patents for the manufacture of self-oiling springs for the replacement trade, and it anticipates a large business in this line.

The W. N. Best Furnace & Burner Corp, New York, has been incorporated with $1,000,000 capital stock, by M. Roger, R. J. Sykes and W. H. Gillen, 1246 Pacific street.

A 40-page booklet in its third edition has been published by the Refractories Manufacturers' Association, containing the names and address of all the manufacturers of refractories in the country. This booklet also lists alphabetically all the various brands of fire brick and other refractories made by respective manufacturers. Copies can be obtained without cost upon application to Secretary Frederick W. Donahoe, 840 Oliver building, Pittsburgh.

A 20-page booklet recently published by the Steel City Testing Laboratory, Pittsburgh, describes and illustrates the hydraulic testing machines built by that laboratory. A feature of the pamphlet is the description and cross sectional diagram of a hydraulic rending and testing machine. The last few pages are devoted to Brinell testing machines and their operation, two hardness tables of diameter and depth of 10-millimeter steel balls being included.

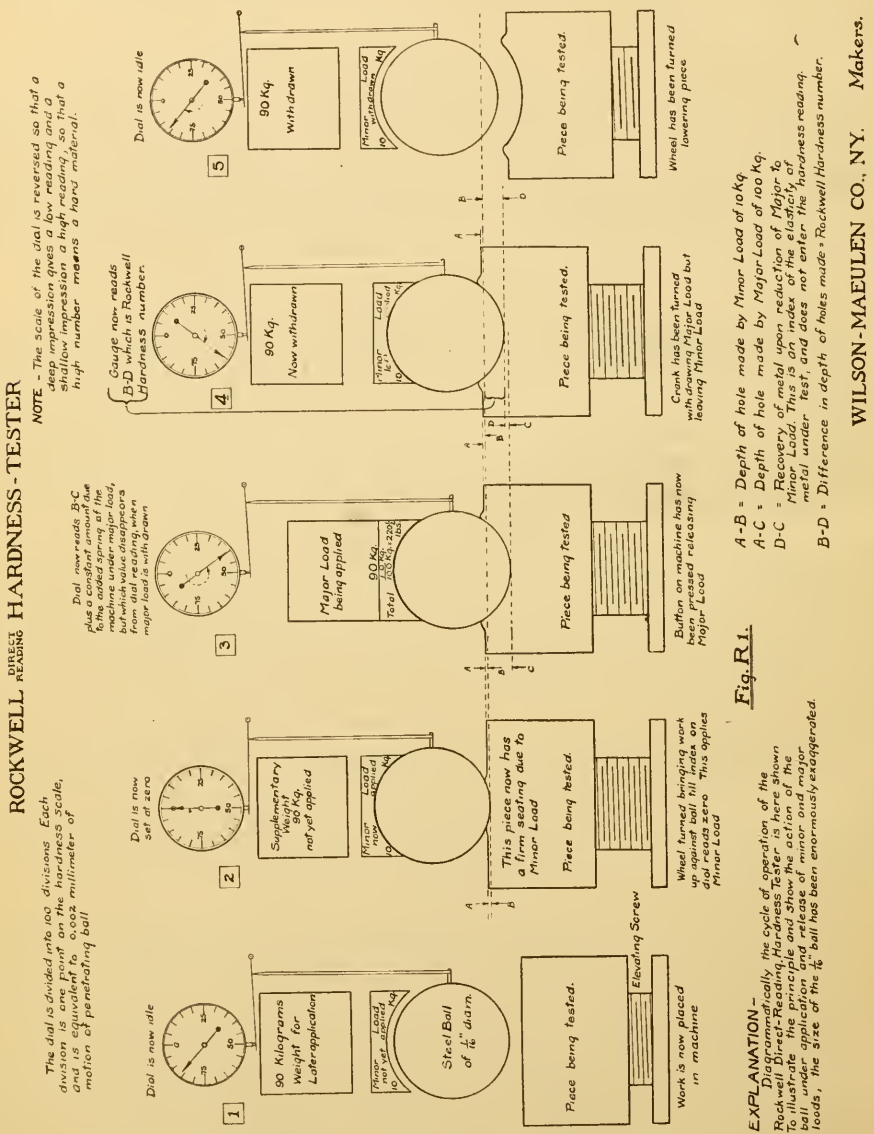
Packard Freight Transportation Digest, Vol. 3, No. 14, published by the Packard Motor Car Co., Detroit, contains an article entitled "Looking Inside Truck Steel To Find Economy and Long Life." This article discusses in plain language various heat treatments to which steel is subjected to secure the necessary requirements for service. A number of sketches and photomicrographs are used as illustrations. The purpose of the article is to acquaint motor truck buyers with the careful attention given the stressed parts of trucks.

"Control in Annealing," by George P. Mills, sales engineer, Electric Construction Co., Philadelphia, was published in the February publication of the Association of Iron and Steel Electrical Engineers. This paper, which was presented before the Philadelphia section of the association, shows the close setting of control devices necessary to secure the desired results.

"The Application of Gas Fuel to Forging," a paper presented before the American Gas Association by the industrial heating department, Henry L. Doherty & Co., New York, is published in the March 17 issue of the *Iron Age,* page 703. This article gives the requirements for a satisfactory forging furnace fuel and compares oil with coal.

Scientific paper No. 408, published recently by the Bureau of Standards, Washington, is a discussion of the "Effect of the Rate of Cooling on the Magnetic and Other Properties of an Annealed Eutectoid Carbon Steel." Eutectoid carbon steel specimens were cooled from 800 degrees Cent. in air in lime and at various rates in a furnace. The effect of these rates of cooling on the magnetic properties of the steel, most important of which are the maximum and residual induction, coercive force, permeability, and the magnetic reluctivity relationship and also the resistivity and scleroscope hardness are shown in tables and discussed. Microphotographs are used as illustrations. The paper shows that the change in structure from an essentially sorbitic one to "divorced" pearlite causes a gradual shifting of the bend in the reluctivity line and a greater difference between the values of the real and apparent saturation intensities.

A small portable direct reading hardness tester recently has been developed by the Wilson-Maeulen Co., 379 Concord avenue, New York. This machine operates upon the principle of employing in succession, a very light load, followed by a heavy load, an automatic indicator showing



the difference in depth between the impressions made by the two loads. In the accompanying illustration is shown and explained the various cycles of operation of the new tester.

(Continued on Page 42, Advertising Section)

TRANSACTIONS
of the
American Society for Steel Treating

Vol. 1 Cleveland, May, 1921 No. 8

AN EFFORT WELL DIRECTED

That the American Society for Steel Treating is spreading its influence beyond the limits of its membership rolls has been demonstrated clearly by successful conclusion of an instructional course recently completed in co-operation with two of Chicago's leading technical schools. Feeling the need for greater education along heat treating and forging subjects, the Chicago Chapter, under the direction of its chairman and Educational Committee, approached the Armour Institute of Technology and Lewis Institute regarding the advisability of conducting a course of evening classes. Both schools approved of the suggestion but because of the lack of experienced instructional material, were unable to conduct the work without assistance. The Chicago Chapter, however, removed this stumbling block by offering instructional assistance recruited from chapter members experienced in various phases of the work. Thus through the co-operation of two instructors, one in each school, and the volunteers from the chapter, a course of study was mapped out for a period of 20 evenings. This course has just been completed with highly gratifying results.

Elsewhere in this issue is contained a detailed account of this educational course together with an outline of the subjects treated in lectures and experiments. Briefly the subjects considered were: Pyrometry, metallography, forging, annealing, alloy steels, hardening and tempering tool steels, and case hardening.

The success of the Chicago Chapter's experiment should encourage other chapters of the Society to initiate and conduct similar courses of instruction. Possibly needs for such education will vary according to the number, size and nature of steel treating industries located in certain localities but modifications can be made to suit local conditions. Because of the remarkable growth of steel treating in recent years and the introduction of alloy steels requiring accurate and varying treatments, the universities, colleges and schools have been unable to provide adequate instruction. Moreover, the men who have been highly trained in metallurgical lines have found places in executive or laboratory positions and have not been able to pass their knowledge down to the practical steel treater.

A significant feature of the Chicago course was that the classes were composed of hardening room workers and students who were eager for training along practical lines. To the average shop worker such training offers exceptional opportunity for advancement and as such opportunities are extended, without doubt, they will enroll in increasing numbers. It

PROFESSOR ALBERT SAUVEUR

is hoped that other chapters of the Society will see fit to encourage the starting of educaional courses and will thus aid in the advancement of the art by passing down the line information of an accurate and reliable character.

PROFESSOR ALBERT SAUVEUR ELECTED HONORARY MEMBER

On Jan. 31 a petition was presented to the Board of Directors containing the nomination of Professor Albert Sauveur, professor of metallurgy and metallography at Harvard University, for Honorary Membership in the American Society for Steel Treating.

This nomination received the unanimous vote of the Board, and consequently Professor Sauveur was elected as the third Honorary Member of the Society.

When Professor Sauveur was in Cleveland on April 22, the certificate of Honorary Membership was presented to him by the National Secretary, W. H. Eisenman acting for the National President, Lieut. Col. A. E. White who was unable to attend.

In presenting the Honorary Membership, Mr. Eisenman gave a brief statement of the life work of Professor Sauveur as follows:

"Albert Sauveur was born in Louvain, Belgium in 1863 of French parentage. He received his early education at the School of Mines in Liege 1881-1886. He was granted an S. B. in Mining and Metallurgy by the Massachusetts Institute of Technology in 1889, and served as chemist and metallurgist for various steel companies including the Pennsylvania Steel Co. and the South Chicago Works of the Illinois Steel Co. from 1889-1897. While at Chicago he began his pioneer work in metallographic research in connection with some heat treatment experiments and published the results in the Transactions of the American Institute of Mining and Metallurgical Engineers, the paper being read at the Chicago meeting in 1893.

"His first microscope was a so-called professional instrument and with an ordinary barrel for a work bench, using sun light as a source of illumination he created that early work which was destined to have such a wide influence on the manufacture and heat treatment of steel in America.

"In 1896 he wrote another paper for the American Institute of Mining and Metallurgical Engineers on the Microstructure of Steel and the Current Theories of Hardening, which summarized to that date, the ideas of various metallurgists regarding the reason for the hardening of steel. This provoked so large a discussion both in America and abroad that it marked an epoch in the history of heat treatment. It clarified the ideas regarding this phenomenon to a remarkable extent.

"In 1899 he was called to Harvard University as instructor and was assistant professor in metallurgy and metallography from 1900-1905. Since then he has been professor of metallurgy at Harvard and at the same time has been very active in committee work for the various technical societies.

"He edited *The Metallographist,* 1898-1903 and *The Iron and Steel Magazine* 1903-1906, and was lecturer on metallography from 1898-1903 at the Massachusetts Institute of Technology. He is an Officer d'Academie and in 1913 was awarded the Elliott Cresson gold medal by the Franklin Institute of Philadelphia. He is a Fellow of the American Academy of

Arts and Sciences and a member of the following societies: American Philosophical Society, National Institute of Social Sciences, American Association for the Advancement of Science, American Institute of Mining and Metallurgical Engineers, holding the office of vice president from 1910-1912; and chairman of the Iron and Steel Committee 1913-1915. He is also a member of the Iron and Steel Institute of Great Britain and of the American Iron and Steel Institute and has contributed valuable papers to the transactions of both of these societies. He was president of the John Fritz Medal Board of Awards in 1916-17. In 1917-19 he was metallurgist of the American Aviation Commission in France and later director of Research for the Metallurgical Division, Air Service, A. E. F. stationed in Paris, where he and his family remained during the German air raids and the long distance bombardment by the Big Berthas.

"Professor Sauveur's best known work is a book entitled 'The Metallography and Heat Treatment of Iron and Steel' but he has written many other articles on metallographic subjects and during the war published two papers entitled 'Germany and the European War' (1915); and 'Germany's Holy War'."

INDIANAPOLIS CONVENTION PLANS PROGRESSING

Wonderful progress is being made for the Convention to be held in Indianapolis Sept. 19 to 24, 1921. Professor H. L. Campbell, of the University of Michigan has been appointed chairman of the Meetings and Papers Committee, and has already set the machinery in motion for securing a set of papers of very high standard, most interesting and entertaining. The suggested topics for papers is printed elsewhere in this issue of the TRANSACTIONS.

The Board of Directors at its recent meeting authorized the awarding of a gold medal to the best paper prepared for the Indianapolis Convention, and approved also the awarding of a silver medal for the second best paper presented at that time. The policy with reference to medals to be followed in the future, is the presenting of these medals for the best papers presented during the year, including, of course, those presented at the Convention.

The Exhibition is making very rapid progress and requests for space have been remarkable. More reservations have been received at this time than were received up until June 15 for the 1920 Exhibition in Philadelphia. The Indianapolis chapter held a meeting recently in which it appointed chairmen of various committees to make preparation for the entertainment of the visitors and their wives in Indianapolis. They are sparing no effort or money to make the Convention a decided success from the standpoint of local entertainment. The various chairmen have organized their committees and have been in constant communication with the National office. It is a foregone conclusion that no detail will be left incomplete which will add to the pleasure and enjoyment of the visiting members.

A list of the hotels at which reservations may be made will be published in the next issue of the TRANSACTIONS.

RESIGNATION OF FIRST VICE PRESIDENT T. E. BARKER

T. E. Barker

T. E. Barker has presented his resignation as first vice-president of the American Society of Steel Treating, to take effect Sept. 19, the first day of the Annual Convention and Exhibition to be held in Indianapolis. Mr. Barker's resignation was presented to the Board of Directors at its meeting in the executive offices in Cleveland on April 9 and was accepted with expressions of deep regret by the entire board.

For fourteen years Mr. Barker was production manager of the Miehle Printing Press Co., Chicago, and withdraws from that firm to become associated with the Denver Rock Drill & Mfg. Co., Denver, Col., on May 1.

Mr. Barker served as the first chairman of the Chicago section of the Steel Treating Research Society and thus became interested in the work and activities which have led to the development of the present organization. When the American Steel Treaters Society was organized he served one year as acting president, and in September, 1919, was elected national president. During the following year the amalgamation of the Steel Treating Research Society and the American Steel Treaters Society progressed to a successful completion and the Nominating Committee of the amalgamated society proposed Mr. Barker as first vice president to serve two years, and he was elected at the meeting in Philadelphia in September, 1920.

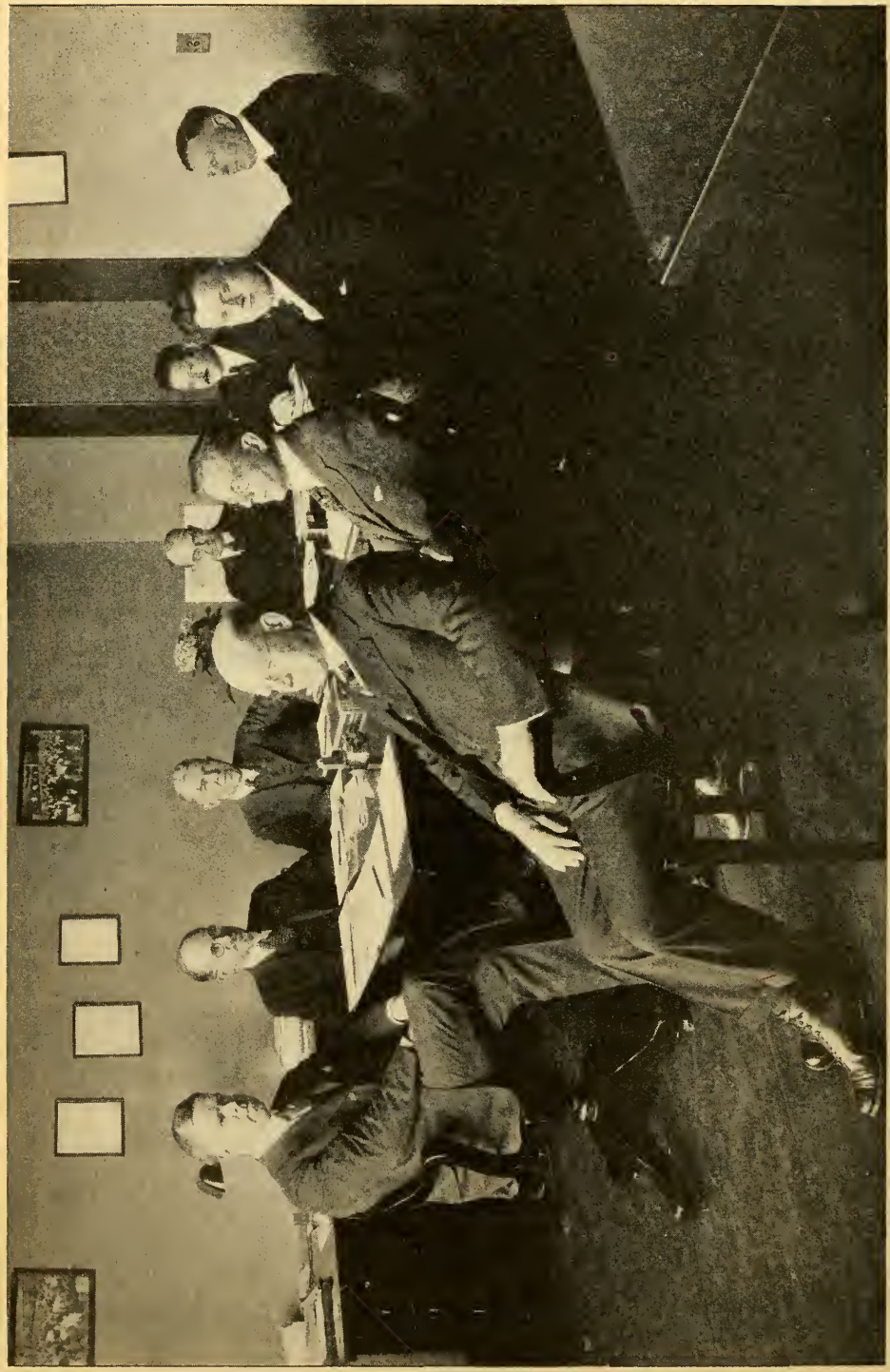
During the time of Mr. Barker's connection with the Society, he has always taken a most unselfish and unbiased attitude, and has always considered only the best interests of the organization. The Board of Directors will feel particularly the loss of Mr. Barker from its councils, yet it sends with him its best wishes for his continued success and prosperity in his new location.

THINGS TO BE DONE

By Arthur W. F. Green*

In comparatively few years the steel treater has risen to an indispensable position in the steel industry and its allied manufactures. While many steel treaters are college men, a great number has been graduated from the great school of experience. The rise of the steel treater has in many cases been from that of common laborer to skilled worker. He is today an artisan. The evolution of the automobile can be traced in no small extent to his untiring efforts coupled with systematic chemical and physical research. Therefore, it is logical to say and think that things have been done, but, there are many things which are as yet only partly done or wholly untouched. If the steel treater is to progress and bring his profession to even higher fame than that already reached, he must attack the partly done and untouched problems and offer solutions in clear, concise, systematic and scientific terms.

* Chief of laboratory, John Illingsworth Steel Co., Philadelphia.



A Photograph of the National Board of Directors at Its Meeting in Cleveland, April 9. Seated from Left to Right Are: Lt. Col. A. E. White, President; T. D. Lynch, Second Vice President; Frank P. Fahy; T. E. Barker, First Vice President; W. S. Bidle, Treasurer; H. J. Stagg; W. H. Eisenman, Secretary; W. C. Peterson; and E. J. Janitzky

Within a very few months the one Society will be holding its Third Annual Convention and Exhibition in Indianapolis. The Convention offers to those who will, a chance to discourse on topics of interest to the membership at large. It is a time and a place where big things count. It is not to be used as time and a place to grind one's ax or otherwise to make a personal show. Drawing upon experience as chairman of the Meetings and Papers Committee last year, the author urges the necessity of preparing readable papers, and papers that substantiate by carefully conducted investigation the points advanced. I wish, therefore, to sow a few seeds in your minds, which will grow into big things and be ripe for the harvest at the time of the Convention. The topics to be mentioned are in need of solution, and to offer a solution which will satisfy, means that intelligent work must be done through mediums of justifiable and reliable research and investigation.

Some time ago I attended a meeting of several typical steel treaters. In the course of the general conversation the question of fiberizing arose. The question came up as to what particular properties the treatment gave to steel, and whether or not there were not other treatments already named and in wide use which imparted the same properties. After much discussion, all present realized that none could give a workable definition for fiberizing. They concluded that the word fiberizing, as applied to heat treatment of steel, was a more or less doubtful term. It is quite possible that all of you could readily define the word and treatment it stands for without one moment's hesitation, but there are many of your co-workers who are not able to do so. We should have some investigation of the subject, supported by microscopic and physical analysis which will substantiate for all time the claims that fiberizing is a definite kind of heat treatment and produces certain results which no other treatment process will do.

If I were desirous of actually starting an argument, I would give you a definition of the process of normalization. I have never read or heard a good definition of it. Only recently, I heard the term used in a paper which was written by one of the greatest exponents of the heat treating art, and I also heard the writer refuse to make his definition general or, in other words, to have an application outside of the particular problem being discussed. What does constitute normalizing? You have your ideas about the matter and I have mine. Who is right? In these days of definitions and laws no term should be allowed to remain in a hazy form if the profession with which we are associated is to progress. We must get down to facts. The correct treatment which is to constitute normalizing must be defined. We must have a common understanding of it and the definition must be backed up by careful analytical work and reasoning. When a normalizing treatment is to be used it must be one particular phase of the series of heat treatment and must not infringe upon a treatment which is already existent.

The decarburization of material in furnaces has usually been accepted as a necessary evil. If any of you attended the Convention last year in Philadelphia, you will recall a discussion that took place in which even the correct word to use was considered. That discussion was printed in full in the March issue of TRANSACTIONS, but I assure you that the hearing was much more interesting than the reading. However, nothing was gained. The factors which go into causing decarburization were not mentioned and the whole matter was left suspended in the air. If research has been done

which is of a beneficial turn it should be placed at the disposal of the steel treater. There must no longer be a secret treatment for this and that. The art is held back just as long as those who profess it do not share their experiences and knowledge. The Convention is the place to air opinions and processes. Opinion especially carries weight because it will always bring an argument. If decarburization is due to certain feature of furnace gases of certain fuels then something is there to be worked on. We must find out.

The oxidation of materials in furnaces has long been a serious problem for the steel treater. Many papers have been written offering solutions of the difficulty and many things which will alleviate the condition, have been produced by minds that are constructive. But, there is much to be done. Everyone of you has read the article by O. Lellep in the March issue of TRANSACTIONS and I believe you will agree with him when he states "the incompleteness and incorrectness of the practical language which often uses the terms reducing flame and oxidizing flame." Mr. Lellep goes a long way toward clearing up some of the cobwebs around the problem, but more must be done if the "incompleteness and incorrectness" is to be changed to "complete and correct practical language." In the March 17 issue of the *Iron Age* an article appears under the caption "Application of Gas Fuel to Forging" and a discussion is included on the subject of oxidation. It is treated of course from a standpoint of fuel application. There are, therefore, efforts being made to arrive at definite conclusions in the matter, but it is my belief that the steel treater has within his grasp the correct answer to the problem if he will get down to work. The Convention is the time to discuss such important problems and the TRANSACTIONS will act as the medium to send them broadcast.

I have by no means covered the subject of things to be done. Some time ago, I was in conversation with the chief research engineer of the United States Army Ordnance Department and he told me of a problem that must be faced. It has been possible to heat treat the armor plate for tanks so that it will resist a 75-millimeter shell but when it is in that condition it will not resist machine gun bullets. If treated to resist the machine gun bullets the shells easily shatter the plates. In his opinion it is a matter for the steel treater to fathom as various conditions have shown that the armor plate used has a great deal in its favor. I only tell you this to say that the problems of the steel treater are indeed varied. He must keep up to the minute in everything connected with the art. He should follow carefully all new developments whether it be in the alloy steels or in the founding of an organization to standardize pyrometers. The steel treater is the exponent of a practically new art. He is going to make that art great in exactly the proportion he gives of himself to its advancement. There are great problems in furnace construction, fuel application, the efficiency of quenching mediums, the use of various salts, and the problem which so often is dodged, efficiency in production, etc.

The Convention is the right place to bring big things for solution. The men who attend may criticize but their criticism is constructive and seldom, if ever, destructive.

There are THINGS TO BE DONE and you are the DOERS.

MANUFACTURE OF STEEL FROM RAW MATERIALS TO FINISHED PRODUCT—REMARKS ON HEAT TREATMENT AND FATIGUE FAILURES

By W. R. Shimer*

(A Paper Presented Before the Springfield Chapter)

Iron ore, limestone and coke are the raw materials used to make pig iron. Of the three large ore bodies located in Cuba, Chile and Cornwall, Pa., and controlled by the Bethlehem Steel Co., the Chilean mine is in some ways the most interesting development. It is located at Tofo, Chile, on top of a mountain which is four miles inland and 2000 feet above sea level. The ore is very rich and pure, containing approximately 68 per cent iron, and is very low in phosphorus and sulphur. The mining operation is an open cut proposition, the ore being picked up by grab buckets and electric shovels and conveyed by an electric tramway from the mines to the coast four miles away. Many million tons of ore are in sight at this mine.

One of the Cuban mines produces a large tonnage of ore containing nickel and chromium. This is reduced in the blast furnace and made into a high grade of pig iron for foundry purposes, containing 2 per cent chromium and 1 per cent nickel. This is called Mayari iron as the ore comes from the Mayari district in Oriente, Cuba. It is an excellent iron for foundry purposes and is used in the manufacture of high grade iron castings such as chilled iron rolls, automobile castings, which include cylinder heads and pistons; chilled car wheels; white iron; heat resisting iron; high test cast iron, etc., by varying the additions of Mayari pig iron to the ordinary pig iron in the cupola.

Iron ore is charged in the blast furnace together with coke and limestone and is reduced to pig iron. An article describing the blast furnace and the method of making pig iron was published in the March issue of TRANSACTIONS. Pig iron, together with certain percentages of steel scrap, a small amount of iron ore and limestone, are charged into the open-hearth furnace for making steel. This discussion of steelmaking will be confined to the open-hearth process as the subject is too broad to include the making of steel by the other processes.

After the material charged into the open-hearth furnace has become liquid, the melter, by means of an iron spoon on a long handle, dips a small amount of metal from the furnace and casts a small test ingot which is fractured and analyzed to guide him in the making of the heat. These tests are taken at intervals from the time the heat is melted until the composition aimed for is obtained, at which time the final additions are made and the heat tapped. The open-hearth melter becomes very expert in judging the carbon content of his bath from the heat test fractures.

Fig. 1, of the accompanying illustrations, shows a number of heat tests taken at various stages of melting, and illustrates the different types of fractures that are obtained during this operation. The percentages written above each fracture indicate the carbon content of the bath as judged by the melter from the appearance of the heat test fracture. The figures written below indicate the actual percentage of carbon as determined by the

*Sales metallurgist, Bethlehem Steel Co., Bethlehem, Pa.

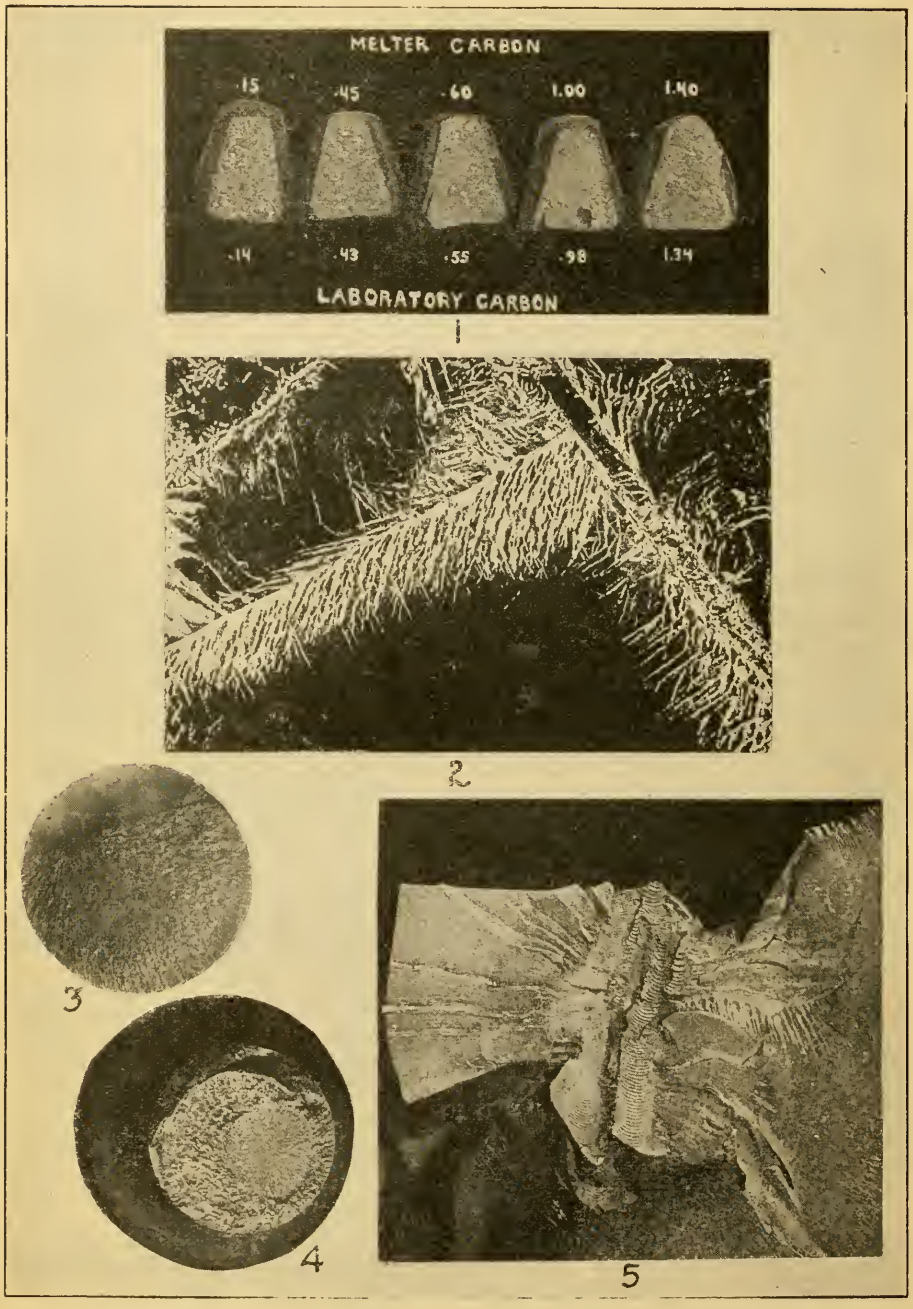
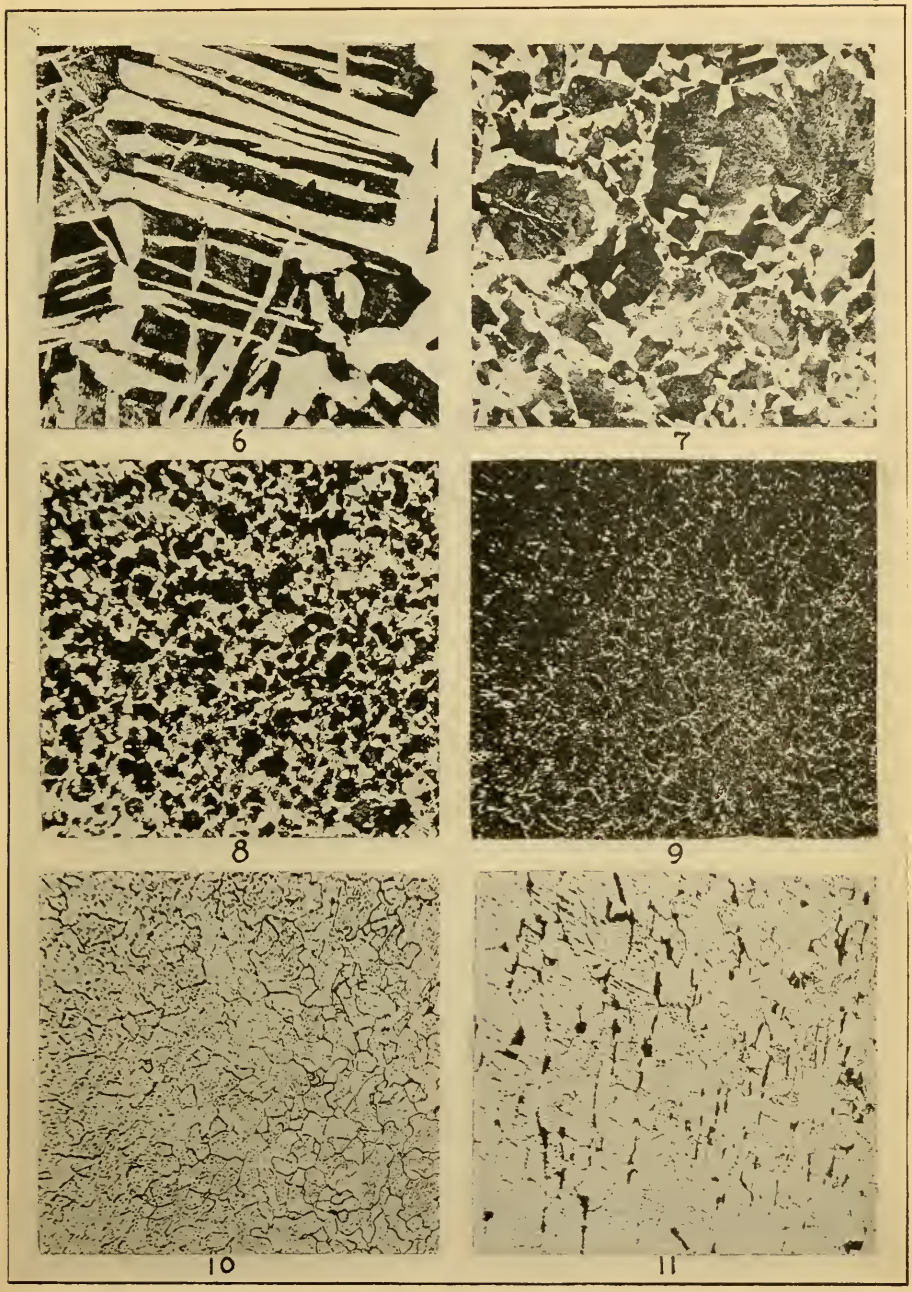


Fig. 1—Heat test fractures. Figures above show melter's estimated carbon content in per cent, figures below give actual carbon content. Fig. 2—Typical microscopic structure of overheated rivet × 100. Fig. 3—Fracture of failed nickel steel drop hammer piston rod. Fig. 4—Fracture of failed rivet set which had been nonuniformly hardened. Fig. 5—Piece from broken steel roll showing fossil fern shape of the progressive fatigue break.



Figs. 6-9—Photomicrographs representing various structural changes from steel ingot to finished forging. Fig. 6—Widmanstatten of ingot indicating slow cooling from high temperature × 100. Fig. 7—Structure of forging as forged × 100. Fig. 8—Structure of forging annealed for machineability × 100. Fig. 9—Structure of forging after final heat treatment × 100. Figs. 10-11—Photomicrographs of iron containing practically no carbon and steel containing carbon up to 1.05 per cent, showing progressive increase of pearlite and decrease of ferrite. Fig. 10—Iron containing 0.01 per cent carbon × 100. Fig. 11—Iron containing 0.10 per cent carbon × 100. All specimens etched with picric acid.

laboratory. By comparing these percentages it will be seen that the melter becomes quite expert in judging fractures and that he checks very closely with the chemical laboratory.

The metal in the furnace is tapped into a ladle, which is conveyed to the ingot molds, and is cast into these molds usually by the box pouring method. Generally, when the size of ingot is not too large, two ingots are poured at one time through the box which has two openings. One of the advantages of this method of pouring as compared with casting into ingots direct from the ladle is that the steel is cooler going through the box by approximately 100 degrees Fahr. Another advantage is that it permits slower pouring which is important in the manufacture of sound ingots. The ideal method for making ingots would be for steel to solidify the instant it was cast, but since this is impossible the manufacturer of high grade steels attempts to cast the steel into the ingot as slowly as possible and at as low a temperature as possible in order to approach as nearly as practicable the ideal condition.

When the metal in the mold has solidified, the ingots are stripped and charged into furnaces for heating prior to rolling or forging. In the rolling operation the ingot is reduced on a blooming mill to sections approximately 8 x 8 inches or 9 x 9 inches, which are conveyed along a runway to the hot shears where the top and bottom discards are cut away and the blooms cut to the desired length. The blooms are then sent to the chipping beds where the surface defects are removed by use of pneumatic chisels. All defects such as seams, laps and scabs, are removed prior to rolling into the finished product.

As mentioned before, the ideal condition would obtain if steel could be made to solidify instantly. If this were possible, segregation of carbon or any of the other nonferrous constituents in steel would be eliminated. Every effort is made by the steel manufacturer to eliminate as much segregation as possible within the limits that nature permits. Segregation increases with the increase in the size of the ingot and is directly proportional to mass and the rate of solidification, the larger ingots solidifying less rapidly than the smaller ones.

Many steel users seem to be of the opinion that the source of slag in steel is furnace slag or ladle slag which becomes imbedded in the ingot. Careful reasoning will show that this cannot be the case because open-hearth slag is so much lighter in weight than steel that it floats to the top of the metal as readily as a cork bobs up in a bath of water when it is immersed and released. To prove this, repeated experiments were made by taking a small test ingot, not larger than 8 to 10 cubic inches, from a ladle of steel which was almost empty, at the time when both steel and slag were dripping from the nozzle together. Upon examination of this test ingot it was found that although the slag and steel ran into the mold at the same time, the slag had separated to the upper part and the lower part was a sound steel button. These small ingots solidified the instant they were cast and therefore in this very short time the slag from the ladle separated, leaving a steel button which was free from slag. Sections of these steel buttons were polished and examined carefully with a miscroscope but no slag could be found.

Additional evidence that this is not the origin of slag in steel, is that furnace and ladle slag contains lime whereas the socalled slag inclusions in

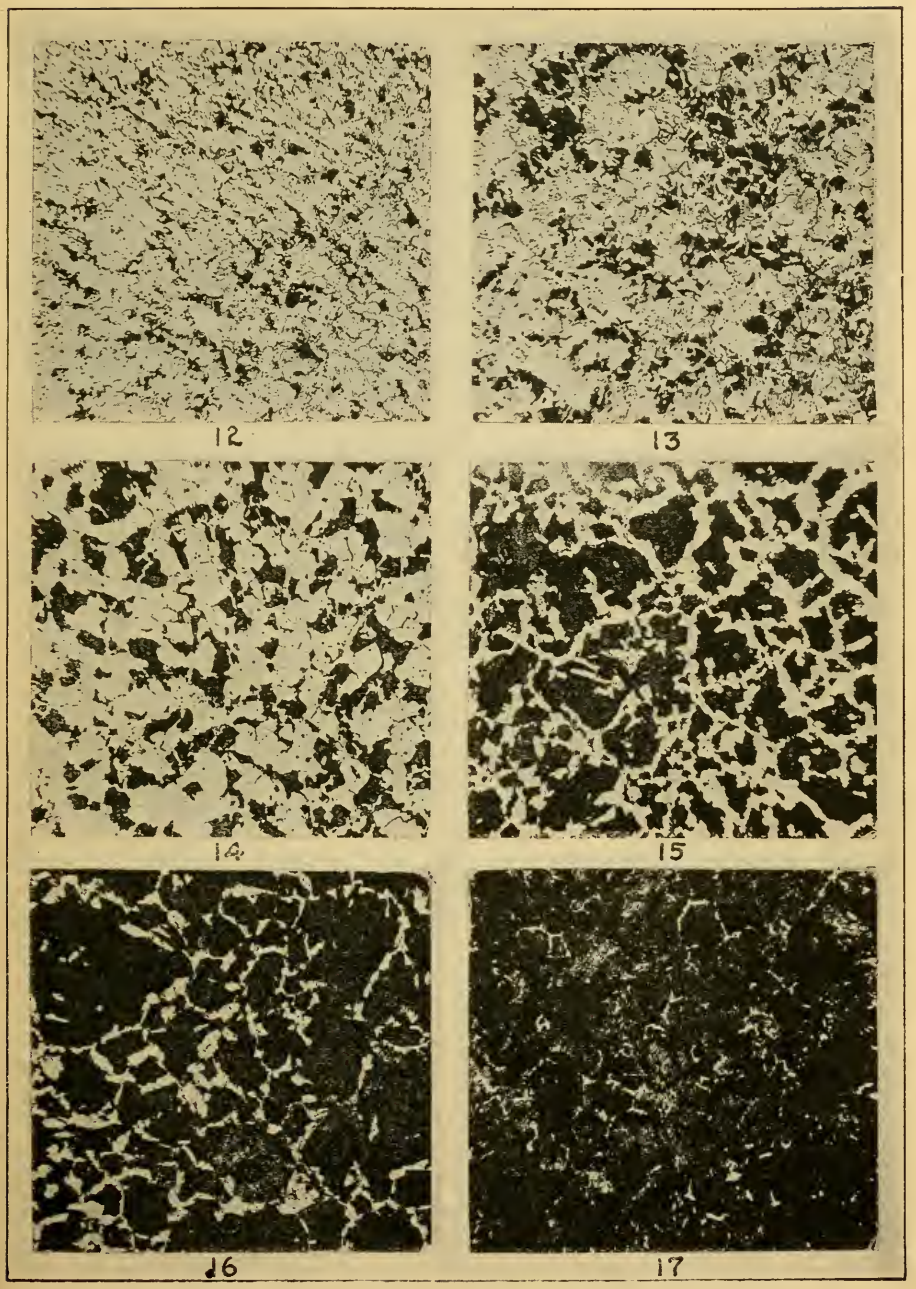


Fig. 12—Iron containing 0.20 per cent carbon × 100. Fig. 13—Steel containing 0.30 per cent carbon × 100. Fig. 14—Steel containing 0.40 per cent carbon × 100. Fig. 15—Steel containing 0.50 per cent carbon × 100. Fig. 16—Steel containing 0.60 per cent carbon × 100. Fig. 17—Steel containing 0.70 per cent carbon × 100. The increase in pearlite and decrease in ferrite is evident as the carbon increases. All specimens etched with picric acid.

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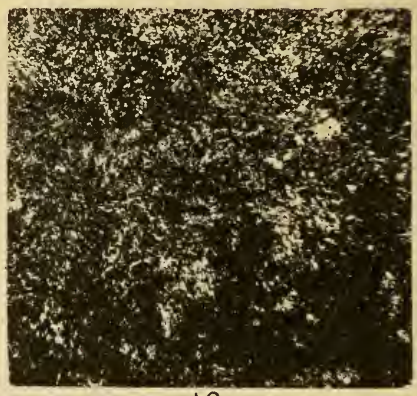
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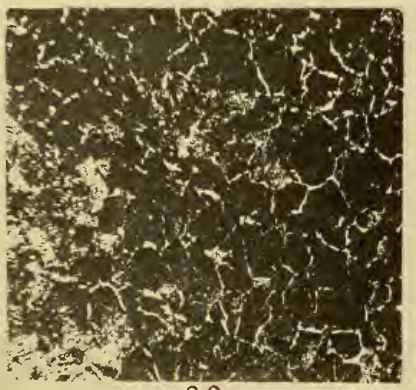
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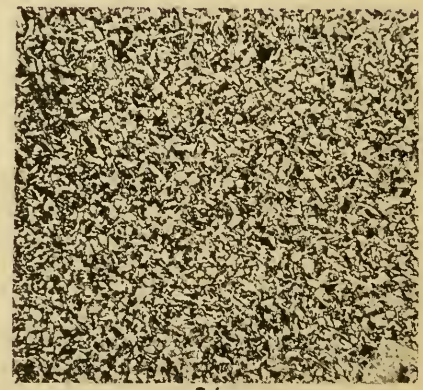
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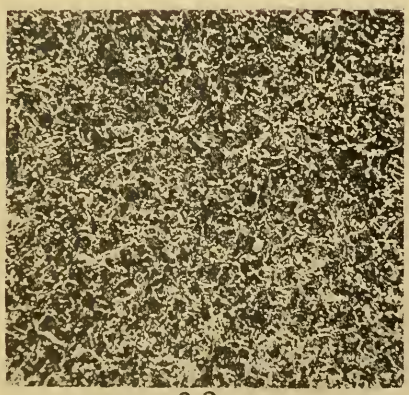
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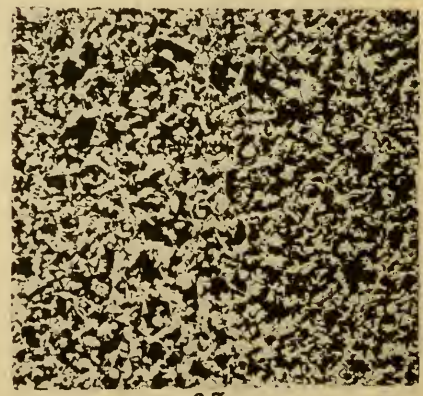
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Fig. 18—Steel containing 0.80 per cent carbon × 100. Fig. 19—Steel containing 0.90 per cent carbon × 100. Fig. 20—Steel containing 1.05 per cent carbon × 100. Here again the increase in pearlite and decrease in ferrite is apparent as the carbon increases. All speciments etched with picric acid. Fig. 21—Structure of test bar of 89,000 pounds per square inch tensile strength × 100. Fig. 22—Structure of test bar of 124,000 pounds per square inch tensile strength × 100. Fig. 23—Structure of test bar, Fig. 21, after reannealing with high tensile bar × 100.

steel consist mostly of sulphides and silicates of iron and manganese, and no lime whatever. The nonmetallic inclusions in steel are caused by reactions occurring in the molten metal in the ingot mold prior to solidification. Some of these impurities work to the top of the ingot as long as the top is molten, but after the upper part becomes solidified and while the interior is still molten, the reaction continues and these inclusions are imprisoned, becoming more numerous as the size of the ingot increases, since it requires a longer time for a large mass of metal to solidify.

The above explains briefly the operation necessary to produce steel from raw materials. At this point it is of interest to examine a series of photomicrographs at 100 diameters magnification, representing the various structural changes in steel during manufacture from ingot to finished forging and exemplifying the effect of the heating operations necessary for the manufacture of a forging from an ingot.

Fig. 6 shows the microstructure of an ingot of Widmanstatten structure and indicates slow cooling from a high temperature. Fig. 7 is the microstructure of a forging in its condition as forged; Fig. 8, the microstructure of the forging after having been annealed for machineability; and Fig. 9, the microstructure of the forging after final heat treatment.

For a matter of laboratory reference a series of micrographs was made to show the structure of iron with practically no carbon and steel containing carbon up to 1.05 and to show the increase in pearlite with the increase in carbon content of the metal. This series is shown by Figs. 10 to 20 inclusive.

Fig. 10, iron which contains carbon, Fig. 11, contains 0.10 per cent carbon, and Fig. 12 contains 0.20 per cent carbon.

Each succeeding micrograph represents steel containing carbon 10 points higher than the one preceding. The increase in pearlite with the increase in carbon content is readily noticed and the decrease in ferrite up to 0.90 per cent carbon also is apparent. The white net work in the micrograph representing the 1.05 per cent carbon steel, Fig. 20, is cementite or free iron carbide.

Some time ago users of rivet steel complained that the heads of rivets either broke off or split after riveting. Representative rivets were examined with the microscope, Fig. 2 showing a typical structure found. That this steel was badly overheated is self-evident. Investigation as to the manner of heating proved that the users had been accustomed to working with low carbon rivet steels whereas these rivets were of high tensile properties, the carbon running from 0.25 to 0.30 per cent and when heated to the same temperature as low carbon rivets became very much overheated, thereby causing the breaking off and splitting of the heads. The consumer was cautioned not to heat the balance of this shipment of high tensile rivets to such a high temperature and future occurrence of the trouble was avoided.

An interesting experience is recalled with one of the foreign inspectors several years ago when he took a tensile test from each end of a ½-inch round bar and obtained 89,000 pounds per square inch tensile strength at one end and 124,000 pounds per square inch at the opposite end. He was very much concerned at this variation in physical properties in the same bar and asked that a microscopic examination be made to determine the cause of this variation. The inspector was an experienced metallographist himself. The two test bars were examined with the microscope at 100 diameters and the low tensile bar appeared to be about 0.30 per cent carbon steel and

the high tensile bar about 0.55 per cent carbon. Fig. 21 represents the structure of the bar showing 89,000 pounds per square inch tensile strength and Fig. 22 shows the structure of the bar having 124,000 pounds per square inch tensile strength.

Since no reason was apparent for such a wide variation in carbon content between the ends of a rolled bar of this small diameter, further investigation was conducted. Both of these test bars were annealed at the same time in a small electric furnace to a temperature above the critical point and after repolishing and etching examination showed the microstructures of each to be identical, as shown by Figs. 23 and 24. The analysis of the heat from which this bar was made was about 0.30 per cent carbon and the microstructures represented by Figs. 23 and 24 also indicate a carbon content of about 0.30 per cent. The fact that identical microstructures were obtained from each of the tensile specimens after annealing above the critical point indicated the cause of the original variation in tensile strength to be due to nonuniformity of annealing the mill length bar after oil quenching.

The end having 124,000 pounds per square inch tensile strength, had been annealed at a low temperature, and the opposite end having 89,000 pounds per square inch tensile strength was overannealed. This lot of bars was retreated with special attention paid to annealing them uniformly and they passed the required test and were finally accepted. This brings up the point of the uncertainty of judging the percentage of carbon in steel from its microstructure. It is possible to make a fair guess when all steels have been annealed at a uniform temperature but in the case just described the carbon was identical at both ends of the bar, whereas, judging from the microstructure the carbon appeared to vary by 25 points.

This recalls a case which proves that it takes considerable courage to interpret a micrograph without knowledge of the history of the specimen it represents. At one time the author was asked by one of the newly employed chemists to tell him what a certain picture he had in his hand represented. This picture appeared to be a photomicrograph of steel but it was not wise to give him an opinon of the structure without knowledge of what it represented. He was told however, that it resembled steel of about 1.10 per cent carbon after etching with sodium picrate, which darkened the cementite boundries leaving the pearlite crystals white.. Being asked what it did represent, the chemist stated it was a sample of Tennessee mud after having been rained upon and dried in the sun, causing it to crack into crystalline form. Fig. 34 is the photograph shown by the chemist, it being 1/6 of the actual size of the mud cakes. This similarity naturally aroused interest, thus a search of the files was made and a photomicrograph of a 1.10 per cent carbon steel taken after etching the steel with sodium picrate found and matched with the picture of the Tennessee mud. Fig. 35 shows the microstructure of this high carbon steel magnified at 300 diameters. Examination proves that the size, type and general appearance of the crystals are identical; so much so, in fact, that they could have been taken from the same object. Here we have a picture of mud 1/6 size and a picture of steel magnified 300 times so nearly alike that they could almost have been printed from the same negative. It is interesting to note if the

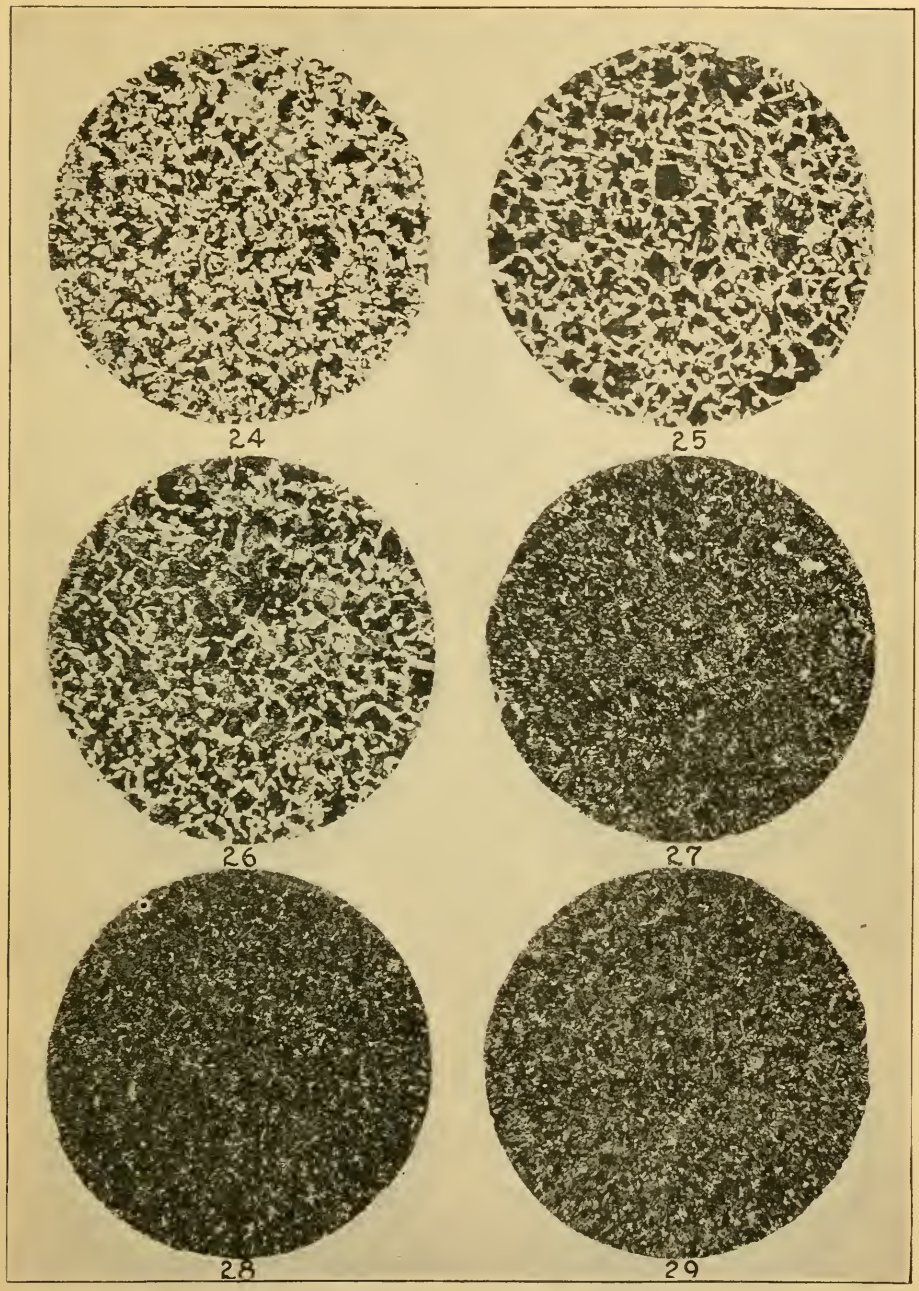

Fig. 24—Structure of test bar, Fig. 22, after reannealing with low tensile bar × 100. Fig. 25-33—Photomicrographs of 0.55 per cent carbon steel quenched at various gradients from 1300 to 1800 degrees Fahr. Fig. 25—Quenched at 1300 degrees Fahr. × 100. Fig. 26—Quenched at 1350 degrees Fahr. × 100. Fig. 27—Quenched at 1400 degrees Fahr. × 100. Fig. 28—Quenched at 1450 degrees Fahr. × 100. Fig. 29—Quenched at 1500 degrees Fahr. × 100. All specimens etched with picric acid.

mud crystals were magnified as many times as the steel photomicrograph the size of one mud crystal would be 75 feet in diameter.

The microscope is a valuable aid to the steel investigator but the example just shown emphasizes the necessity of having a full knowledge of the object in question before an intelligent interpretation can be made. Another case of interest is that of a lot of several thousand miscellaneous forgings of high carbon steel carbon content 1.10 per cent, varying in weight from approximately 10 to 20 pounds each. These forgings were to meet a specification of over 18 per cent elongation in 2″. They were quenched and annealed and the tensile bars broke short, having elongations of only from 7 to 9 per cent with no contraction of area, and the fractures were coarse crystalline. A number of retreatments were resorted to without benefiting the elongation and as there seemed to be no hope in passing the steel it was finally put up to the metallographist to determine the cause of brittleness which the heat treatment man claimed to be due to poor steel. Fig. 36 is a

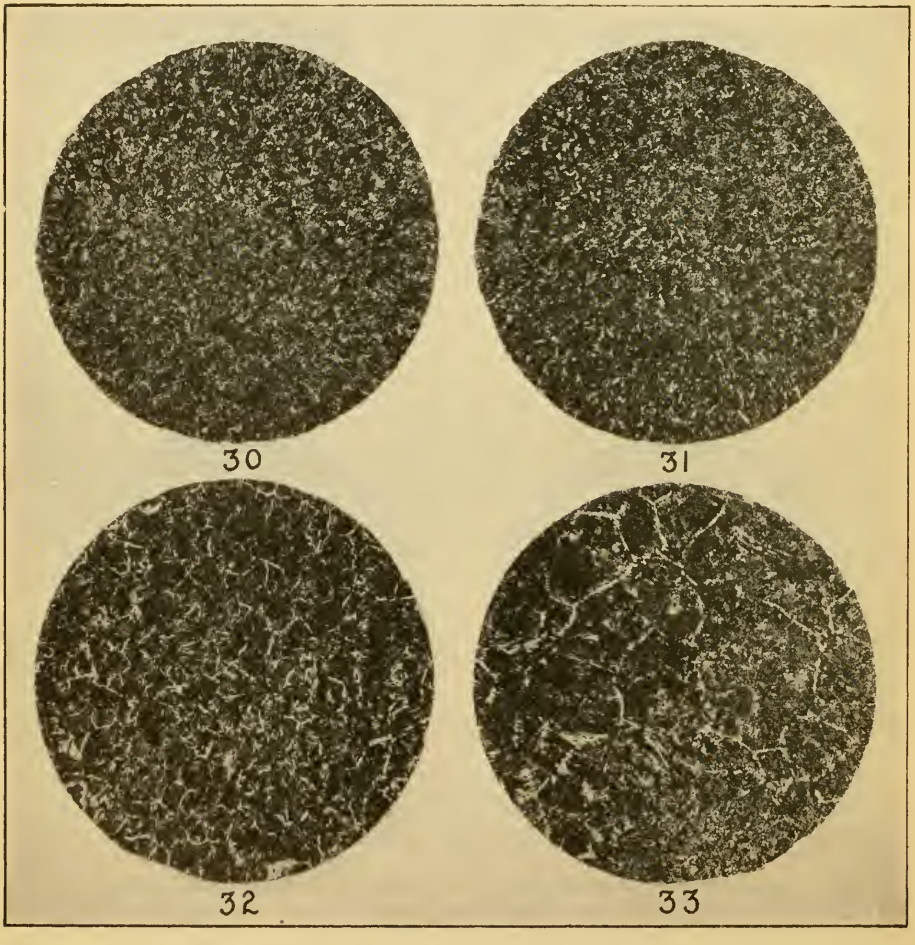

Fig. 30—Photomicrograph of 0.55 per cent carbon bar quenched at 1550 degrees Fahr. × 100. Fig. 31—Quenched at 1600 degrees Fahr. × 100. Fig. 32—Quenched at 1700 degrees Fahr. × 100. Fig. 33—Quenched at 1800 degrees Fahr. × 100. All specimens etched with picric acid.

micrograph of this steel magnified 300 diameters in its unacceptable condition. The specimen had been etched with sodium picrate turning the grain boundaries dark, and shows that each crystal was surrounded by the brittle microconstituent, cementite.

Acting on the theory that cementite goes into solution at about 1600 degrees Fahr., it was suggested that the forgings be retreated by heating to this temperature, soaking thoroughly, and then quenching in oil to keep the cementite in solution. This was done and the forgings were reheated afterwards to the proper hardening temperature and oil quenched, followed by an annealing at about 1100 degrees Fahr. As a result, 132,000 pounds per square inch tensile strength was obtained with elongations well over 18 per cent. Fig. 37 shows the microstructure of this steel after the double heat treatment. The specimen was etched with sodium picrate and shows that the cementite is in small well scattered specks.

Cementite, having a theoretical tensile strength of 5000 pounds per square inch and no elongation when it occurred along grain boundaries, caused weak junctions between the pearlite crystals thereby accounting for the brittle condition when these forgings were improperly treated. After being broken up into small disseminated particles, as just explained, the cementite did not have this weakening influence and sufficient ductility was obtained by correct heat treatment so that these several thousand forgings were finally accepted.

Many heat treaters assume the quenching temperature for a certain grade of steel coming within specified chemical limits of carbon, manganese and the other elements, to be uniform regardless of heats. This is true to a certain extent but for certain grades of steel for special purposes it is not true. Variations in quenching temperature of 10 to 20 degrees Fahr., either too high or too low, at times will influence the service properties of certain parts. For important parts the proper quenching temperature should be determined for each heat of steel used and also for the different sizes of stock from each heat of steel.

A most practical method for determining the correct quenching temperature is to select a number of specimen bars from a heat of steel and heat one of them to a temperature known to be at or just below the critical point. Heat another bar to a temperature 25 degrees higher, increasing each bar by about 25 degrees until a point well above the critical point is reached. Quench these bars at the various temperatures and then fracture them. The correct quenching temperature for that stock can be determined from the appearance of these fractures. This can be demonstrated best by a series of photomicrographs which have been made from steel of 0.55 per cent carbon and representing bars quenched at temperatures ranging from 1300 to 1800 degrees Fahr. For convenience in sawing and examination, all the bars were annealed together at 175 degrees Fahr., which did not effect the variation in grain size obtained by the various quenching temperatures. All micrographs are magnified 100 diameters.

Fig. 25 was quenched at 1300 degrees Fahr.; Fig. 26 at 1350 degrees; Fig. 27 at 1400 degrees; Fig. 28 at 1450 degrees; Fig. 29 at 1500 degrees; Fig. 30 at 1550 degrees; Fig. 31 at 1600 degrees; Fig. 32 at 1700 degrees; and Fig. 33 at 1800 degrees. Upon studying these photomicrographs, it will be noted that up to 1350 degrees Fahr. the quenching temperature was too low and at 1400 degrees Fahr. the steel partially responded although

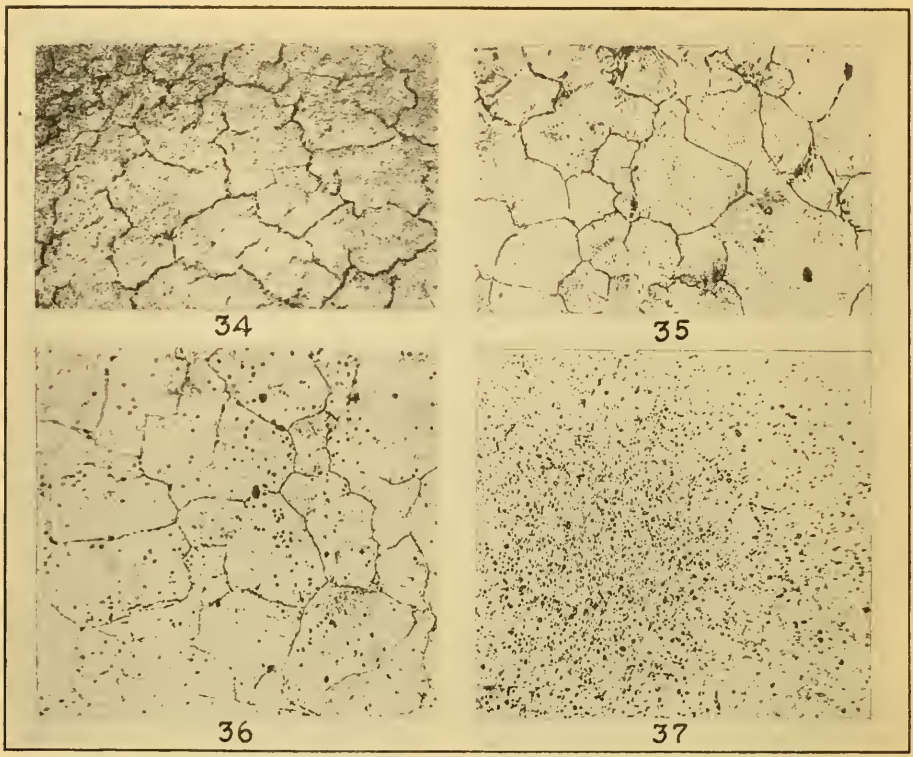

Fig. 34.—Photograph of dried Tennessee mud, 1/6 actual size. Fig. 35—Photomicrograph of 1.10 per cent carbon steel × 100. Etched by boiling with sodium picrate. Note the similarity to Fig. 34. Fig. 36—Microstructure of 1.10 per cent carbon steel of low elongation × 300. Fig. 37—Microstructure of 1.10 per cent carbon steel of good elongation × 300.

there was still some free ferrite remaining, indicating the quenching temperature was not quite high enough. The best grain refinement for this steel was obtained in the bar quenched at 1500 degrees Fahr., although this temperature is well above the critical point of the steel which was approximately 1360 degrees Fahr. The size of this bar was 2 inches in diameter but regardless of its actual critical point we have determined by this method the proper quenching temperature for a 2 inch section of this heat of steel. The correct temperature of say a ½-inch diameter bar from the same heat of steel would be considerably below 1500 degrees Fahr. It is important, therefore, to determine in some such manner as this the correct temperature for important parts of various sizes from the same heat of steel.

There is the old saying about "an untreated alloy steel or an improperly treated alloy steel being inferior to carbon steel" which contains much truth and, therefore, if an alloy steel is not properly treated the value of the alloys is lost. A properly treated alloy steel, however, has service properties superior to carbon steel and in this case it is well worth while to pay the additional cost as this grade will far outlive the ordinary grades.

Fig. 3 is a reduced photograph of the fracture of a broken nickel steel drop hammer piston rod. This fracture is representative of a quite usual

type of a fatigue failure. The nucleus of this fatigue was at the surface of the bar and it finally grew inward during continued service until there was not sufficient cross section to keep the bar intact and it finally caused complete fracture. This case came up as a complaint some years ago, the user of the steel being a new customer who ordered nickel steel bars of certain sizes which, as is recalled, were about 3 or 3½ inches in diameter. The producer was not advised as for what the customer intended to use the steel and, therefore, the order went through in the regular manner and the bars were shipped in the annealed condition, having received a simple annealing for machineability. Some time later a complaint was received that this socalled "special alloy steel was the worst material they had ever used, it being inferior to wrought iron and brass." Investigation proved that these bars had been machined into pistons for drop forge hammers. One broke after five hours service; another after 20 hours service, while a third lasted almost five days. After machining into pistons they had received no heat treatment.

It so happened that some steel from the same heat and not having been machined, was still available and was sufficient to make seven piston rods. This steel was returned to the works upon the producer's request, given an oil treatment and annealing and was reshipped to a customer who machined them into pistons, installed the pistons in drop forge hammers and as far as is known, "they may still be in service as the last report received was they were very satisfactory." This illustrates a case where the nickel steel was unsatisfactory for service in its annealed condition; which can be considered for this purpose in its untreated condition, and how the same steel was made satisfactory by the proper heat treatment.

Fig. 4 shows the fracture of a failed rivet set which had not been uniformly hardened, the chill being thicker at some portions than others causing it to fail after short service. This caused a fatigue failure due to unequal strains on account of nonuniform hardness. This same steel uniformly hardened at the right temperature will give satisfactory service.

Fig. 5 represents a peculiar type of fatigue break occurring in a hardened steel roll. This break grew in a peculiar manner assuming a fossil fern shape. The author does not know how this occurred, it being a new type seldom occurring, but it is shown merely as another freak of fatigue.

From the standpoint of the steel manufacturer, it will be understood readily that naturally he is interested in having the steel he produces heat treated in the best possible manner that is practicable. The responsibility for failures due to metallurgical defects such as serious segregation, pipe, etc. unquestionably rests with the steel manufacturer. There are, however, many cases of failures due to faulty heat treatment or poor design which can not be attributed to the steel manufacturer but for which many times he is asked to pay the cost. However, since the science of heat treatment is advancing, these cases are fewer in number.

MAKING THE MOST OF HIGH SPEED STEEL

By A. J. Wilson*

(A Paper Presented Before the Indianapolis Chapter)

High speed steel is of vital importance to all lines of manufacture, for there is no manufacturing concern that is not more or less interested in the use and conservation of tools and tool steel. This applies more especially to the automobile or automobile parts manufacturer whose tools, particularly high speed steel tools, are a very large item of expense.

During the war when the price of high speed steel was very high, we were awakened rudely to the fact that we were using this material in an extravagant manner. As production of war material was the important demand at that time, the only alternative was to buy more steel as needed. But we also got busy to find some means of making this high priced steel stay on the job longer and to do more work while it was on the job.

As it was necessary to have a starting point, this was made at the blacksmith forge. Due care was taken that heats were satisfactory when the forging was done. One point that the forge man must make certain is that his steel is heated through uniformly. The outside may be up to forging heat and the inside many degrees cooler. The effect of this can be appreciated readily if a piece of steel in this condition were to be put under the hammer. The outside being softer than the center would prevent the hammer blows from displacing the metal in the center of the piece, therefore it would cause a number of small ruptures which undoubtedly would cause trouble in hardening.

No tools should be hardened direct from the forging operation, but should be annealed before hardening. To save time this may be done by heating them to about 1650 degrees Fahr. in the forge fire and then burying them in ground mica which for convenience can be kept in a cast iron box near the forge. Air slacked lime also will answer the same purpose.

After being annealed the tools are ground before hardening, so as to have the least possible amount of stock to remove after the hardening operation. In hardening high speed steel the advantages derived from proper reheating cannot be overestimated. Preheating to 1450 to 1550 degrees Fahr. in a slow furnace and then bringing the heat up quickly to 2250 to 2300 degrees Fahr. in another furnace generally gives satisfactory results. Although in the case of an intricate tool which is liable to crack, better results may be obtained by two preheats, one about 1450 degrees, another about 1750 degrees Fahr., and from this placing the tool into the hardening furnace. Handling the tool in this manner, the shock of being transferred to the hardening temperature is not so great and aids by not causing quick expansion of the thinner sections which naturally heat the more rapidly.

The supposition that any fire is good enough for a preheat is erroneous, because the same care must be exercised in running a furnace for preheating as for final heating if best results are to be obtained and the tool is to come out free from scale. Tools must not be allowed to soak in the preheating furnace.

As a quenching medium, fish oil, a standard soluble quenching oil or coal oil will give good results. Coal oil is a little more drastic and it must

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be used with some caution on account of its inflamable nature. For turning tools, boring tools and the like, where points only are hardened and a little scale does not matter, an air blast will be found satisfactory provided that the air is free from moisture.

During the past few years much experimenting has been done in tempering or drawing back of high speed steel tools and it is along this line that the most improvement has been made. Drawing back has been a common practice for years but not to the extent that it is now carried on. It has been found that steel of standard make when properly hardened, using as high a heat as can be used safely, then drawing back to 1050 or 1100 degrees Fahr., will give its best service. This applies more directly to tools doing extremely heavy work and those required to remove a large amount of metal. The tool is tougher and stronger, still retaining its original hardness, and is not given to crumbling on the cutting edge.

With tools required to give a smooth finish and take a light cut, drawing at so high a temperature is not recommended but a draw of approximately 425 degrees Fahr. in oil has been found to give satisfactory results. A tool drawn at this temperature will retain a keener cutting edge on light work than one drawn at 1000 degrees Fahr. Drawing through the intermediate temperatures, that is between 425 and 1000 degrees Fahr. has not, to the writer's knowledge, ever been productive of any marked degree of success. In fact if it were found necessary to draw a tool made of high speed steel beyond 500 degrees Fahr., it is preferable to jump to the upper range. A chart put out by a well known maker of steel gives some very valuable information in regard to high temperature drawing. This chart gives 800 degrees Fahr. as the point at which the greatest softness occurs.

Before being put to work tools must be properly ground, care being taken to avoid drawing temper or checking. It is customary to use a dry wheel which should be free cutting and true. If water is used sufficient must be used to keep the tool cool as alternate heating and cooling is very conducive to cracks or small checks which will cause trouble later on.

An occasional bar of steel will contain a pipe or seam. This can be determined easily by the appearance of the crack in the hardened tool and if the bar of steel from which this tool was made is examined, the seam or pipe generally can be discovered without much difficulty. Such a bar is practically worthless, but such cases are rare and most of the failures in tools can be laid at the door of the men who handle the steel after it is in the manufacturing plant. In other words, there is much more trouble due to faulty methods of handling than to defective steel.

Now that the tool is ready for use how can we get the most out of this tool? In using the term tools we are referring to tools for removing metal such as are used in turret lathes, screw machines, engine lathes, etc. In the writer's company there is employed a man whose title is "Turning Tool Supervisor", his duty being that of providing the workmen with proper turning tools.

It might be well to mention at this time that 90 per cent of the work is performed under what is known as the straight piece-rate system. Any one connected with manufacturing where a bonus or straight piece rate is in effect, knows from experience how essential it is to keep workmen supplied with proper tools. The average man working straight day rate will

find little fault with his tools if they are not of proper shape and right hardness. He will probably reduce his feed and speed to the point where they will stand. Put this same man under one of the above mentioned methods and if tools do not stand up he will soon be heard from.

Some time back, this problem confronted our company and after consideration it was decided to appoint some one man whose duty it would be to furnish the workmen with tools properly forged, hardened and ground. By this arrangement a saving on tools was effected and production was increased between 15 and 20 per cent. One of the foremen was selected for this new position and he had a man's size job, for in a shop where this method has never been tried it cannot be accomplished over night. One of his first problems was to gain the confidence of the workmen. Second, he was compelled to sell them the idea that a certain new shaped tool would do the work as well or a little better than a certain shape of their own pet idea. It is also a well known fact that no two workmen will grind a tool alike but this was overcome by using a mechanical tool grinder. Using this as a starting point we were soon able to convince the men that tools could be ground better and cheaper mechanically than by hand.

This point being accomplished, a systematization of work was begun. When a tool was adopted as a standard to be kept in stock, it was given a number and a tracing made of it for the producing of blue prints to compose a file of the growing list of standard tools.

One tool stock room supplies the three tool cribs. From these cribs tools are checked out to the workmen and are to be returned as soon as their job is done. This does away with the old method of each workman keeping an unnecessary amount of tools at his machine, a system which is very costly. Each department is equipped with an emery wheel stand to be used in resharpening tools while in use, this being the only grinding done in the machine shop as all tools are shaped up and ground when they are checked out to the workman.

When a tool is broken or ground beyond resharpening, it is turned back to the crib and replaced by a new tool. These broken or worn tools are kept in a place by themselves in the crib until they are collected by the tool supervisor who has them salvaged by being reforged into some other tool using a lesser amount of steel or welded onto carbon steel shanks.

Tools that have been reforged and ground away until they are about 4 inches long are considered ready for the electric welder where they are welded onto carbon steel shanks in an electric butt welder. Very little has been written about this method of salvaging tools and from what data has been gathered in the past year or so, we find that very few firms have taken up this method of salvaging worn out turning tools, crop ends of bar stock, etc. Before going into the cost of salvaging this steel by welding, it might be well to explain the method used in preparing tools and shanks for welding.

We will take for example a piece of high speed steel ¾ x 1 x 8 inches long, which length represents the majority of our tools. Of this length, approximately 4 inches is used, leaving 4 inches, which if not suitable for reforging into some other tool formerly was sold for scrap. At the length of 4 inches the average tool is of no further use as it cannot be held successfully in a tool post or other clamp while in use. These scrap or crop

ends are taken to the blacksmith forge where the forged end is cut away with a hot chisel. Then it is taken to a grinder where the ends are ground at right angles with the sides. It is now ready for being welded to a carbon steel shank, which shank is made from 0.25 to 0.35 per cent cold-rolled carbon steel.

For tools larger than ¾ x 1 x 8 inches it is advisable to use shanks of higher carbon. Our experience in welding heavier tools has been quite limited, but we have been informed by good authority that steel containing 50 to 60 per cent carbon is satisfactory for welding onto heavier tools up to 2 inches square, such as tools used on large planers, boring mills, wheel lathes, etc.

The value of a solid high speed steel tool of the size just stated, is as follows. One piece ¾ x 1 x 8 inches weighs approximately 1.7 pounds and costs about $1.00 per pound or $1.70. To this we add cost of labor plus 50 per cent overhead as follows:

Forging	$0.10	
Grinding	.05	
Hardening	.04	
Total labor		.19
Overhead		.095
Price of steel		1.70
Total cost of tool		$1.985

This is practically $2.00 for a small tool ready to be put to use. Of course the labor figures are only approximate, but will come very close to actual cost, and the overhead will vary in different plants.

Now let us find the cost of a tool of the same size, one half high speed steel and one half carbon steel. One piece of the high speed steel ¾ x 1 x 4 inches weighs 0.85 pounds which at $1.00 per pound represents $0.85. One piece of carbon steel of the same size, weighing about 0.80 pounds at $0.07 per pound represents $0.056. Further costs are as follows:

Cutting off carbon steel from bar	$0.01	
Welding	.015	
Annealing	.03	
Forging, hardening and grinding	.19	
Total labor		.245
Overhead		.12
High speed steel cost		.85
Carbon steel cost		.056
Total cost of tool		$1.271

From these figures we find that where as our tools of solid high speed steel costs $1.985, we can produce a tool of one half high speed steel and one half carbon steel welded on which answers the same purpose for $1.271 with a net saving of $0.714.

Now let us see how cheaply we can produce a first-class tool from scrap formerly sold at $0.10 per pound, that is a tool of the same size worn down to 4 inches in length or too short to hold in a tool post. The cost is as follows:

Cutting off forged end of worn tool	$0.015
Grinding end square	.01
Electric welding	.015

Annealing	.03	
Cutting off carbon shank	.01	
Forging, hardening and grinding	.19	
Total labor		.270
Overhead		.135
Cost of 0.85 pounds high speed steel at $0.10 per pound		0.85
Cost of 0.80 pounds carbon steel shank at $0.07 per pound		.056
Total cost of tool		$0.546

Thus we find that we have the following results:

Tool made from solid high speed steel	$1.985
Tool made from one half high speed steel and one half carbon steel	1.271
Saving	$0.714

Now we have produced a tool by salvaging for $0.546 with or a direct saving of $1.439 over a solid tool of high speed steel, also a saving of $0.725 over a tool welded up from a piece of steel representing 100 per cent value.

One peculiarity arises in welding high speed steel and carbon steel, that must be overcome, and that is; one will heat faster than the other owing to the difference in resistance. This will occur in any two pieces of metal that are of different composition. This is overcome by allowing one to project further from the holding dies than the other until they seem to heat evenly to a plastic heat, then they are pressed together. The amount that they must differ in length to get proper heat at welding points can only be determined by experimenting.

As soon as the welding is accomplished they must be annealed. This is best accomplished by placing them in a hot furnace, holding them at a good annealing heat for an hour or more, then letting them cool down slowly in the furnace. If a piece of high speed steel and carbon steel when welded together is allowed to cool in the air, one will cool quicker than the other, and as contraction takes place during cooling it is bound to set up a strain in the weld which will cause it to crack. This will be true five times out of ten, thus it does not pay to take any chances. Tools properly welded and annealed can be forged successfully and it is our experience that less than 0.5 per cent break in forging.

In placing these tools in service, precaution should be taken to see that the bed of the tool post is level and smoothed where the tool is clamped down or it may be broken in this way. This is equally true of any high speed steel tool that has been hardened all over.

The habit of workmen in striking a tool with a hammer when it is necessary to move it cannot be condemned too strongly. It is much better to take a little longer, relieve the tool and reset it, as a broken tool costs money and time and produces nothing but waste.

In conclusion, the price of success is eternal vigilance. Workmen, as a rule, do not take interest in the use of tools, and the practice of economy as that shown by the man who is responsible for the success of the department or the man who pays the bills, but much can be done along the line of educating machine operators in lines of careful handling of tools. They must be taught that every direct loss sustained by the company is an indirect loss to every individual connected with the firm.

HEATING AND QUENCHING HIGH SPEED STEEL

By A. E. Bellis*

(A Paper Presented Before the Boston Chapter.)

One of the recent developments in our civilization is the recognition of the importance, capacity and power of proper large scale organizations. While these have their defects, we all see their advantages. No better example of these can be cited than their power in getting arms and men to Europe so that this country could play its decisive part in the war. The lesson that the steel treater can draw from this is that by organized co-operation with others of his craft he can increase his power and ability and advance his art many times more effectively than by the old secretive process of isolated efforts. One of the greatest problems for co-operative investigations by this heat treating fraternity is the development of a satisfactory theory on which to establish exact and reliable practice for heat treating tool steel.

It is very important that our fundamental conceptions and conventions be correct. Have you ever considered how much confusion would have been avoided if the race had always used the best units for measuring time, length, weight, etc., instead of slowly evolving some compromise systems? How many centuries did it take to establish our present time measuring system of units, years, months, days, etc.? How convenient it would be if we had a number system of eight units instead of ten, so that most of the unwieldy fractions that bob up in our decimal system would be eliminated. How much confusion would be avoided if we had one entirely satisfactory temperature scale? The history of every science gives illustrations of the importance of exact foundations to make the future structure progress symmetrically without requiring the tearing down of misconceptions from time to time.

A review of the history of the art of hardening of tool steel can be made very briefly, and is of interest in explaining some of our present theories and practices. It is surprising how few radical changes and how few important developments are found. Before 1700 there was a volume of literature on the art descriptive of all kinds of quaint and imaginative processes and theories on the hardening of steel. It seemed to be well recognized at that time that the rapid quench or rate of cooling from a high temperature was necessary for hardening. One writer stated, however, that the best hardening resulted from quenching in an infusion from the roots of blue lilies, and that softening of the steel resulted from quenching in an infusion from the common bean. Francis Bacon attributed the hardness to its "youthfulness of spirit"—a phrase that suggests the fatigue phenomenon that is still a mystery although we have established some solid facts and eliminated considerable of the superstition connected with it.

In the eighteenth century the chemists believed in the phlogiston theory and thought that putting phlogiston or heat energy into iron changed it to steel. In 1721 Reaumer suggested the first physical chemical theory to account for hardening, in opposition to the phlogiston theory. He believed that heat drove out "sulphurs and salts" making the iron more compact, and that these salts returned upon tempering. In 1781 Bergman, who believed in the phlogiston theory, demonstrated that steel contained 0.20 per cent of plumbago (carbon) and suggested that

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this might cause a polymorphous change in the iron. While he confused phlogiston with the plumbago, his views were the foundation for our present theories. Shortly after this time Bertholet and Lavoisier demonstrated the elementary nature of carbon and oxygen, so that the phlogiston theory no longer reigned, and the foundation of our present chemical science was firmly established.

During the next 50 years many experiments were made to harden steel with the carbon of the diamond, without any important results from such costly experiments. The relation between the carbon content and hardening power of the steel began to be recognized, and a quantity of excellent empirical data on steelmaking and hardening developed. In 1864 Sorby's wonderful work with the microscope opened up the metallographic field and the results of improved microscopic technique led to the recognition of the "pearly constituent" of soft steel, to Martens' identification of the constituents of hardened steel and to all the results of such later workers as Howe and Sauveur in which the significance of the physical orientation of the proximate components came to be definitely understood. This work was supplemented by the information gained from heating and cooling curves and the recognition of transformation points and their relation to rate of cooling or quenching and structure.

The practical development of tool steel began to make real progress in 1870 when the first special tool steels were produced. These were high carbon steels with the special elements, manganese, tungsten or chromium added, which gave the steel the property of self hardening. These steels had a cutting efficiency two and one-half times greater than the plain carbon tool steels. Real high speed steel was not discovered until 1900, when Taylor and White found that the medium carbon, high tungsten steel when heated nearly to fusion gave a cutting efficiency six times that of the ordinary carbon steels. There have been countless experiments varying the proportions of the essential elements to find the best composition for high speed steel. The standard brands now have approximately 17.0 per cent tungsten, 3.0 per cent chromium, 1.0 per cent vanadium and 0.55 to 0.70 per cent carbon. There are many variations from this analysis but this will be considered as a typical high speed steel in the following discussion.

The unique property of this steel is its ability to work red hot without losing its temper and this red hardness of high speed steel is its valuable property. The limitation of cutting speed on the plain carbon tool steel is the tempering or softening of the tool if run fast enough to heat above 400 degrees Fahr. Some high speed steels actually increase in hardness and cutting efficiency on heating up to 1150 degrees Fahr. This secondary hardening is a complex property depending on composition and heat treatment that has not yet been satisfactorily explained. The actual hardness of high speed steels is not an indication of their cutting efficiency. Taylor, who discovered these steels and studied them extensively, states that the best all round high speed cutting tool can be filed with a hard carbon steel file. It is good policy, however, for the heat treating room to turn out high speed tools that will resist the mechanic's file test. This brings us to the consideration of the heat treatment of high speed steel tools.

It is necessary to heat these steels to very near the melting point in order to get them properly hardened. The old blacksmith used to get

this heat in the coal forge and, to insure enough heat, used to actually melt the corners of the lathe tools he hardened. By regulating his draft he was able to avoid excessive scaling and oxidation. The use of high speed steel for fine edge tools, small reamers, milling cutters, etc., has resulted in the development of more refined methods and careful technique. It is now recognized that properly controlled conditions are as necessary for getting the best results from high speed steel as are necessary for other tool steels.

Too long or too high heating coarsens the grain with resulting weakness and brittleness, while insufficient heat will not develop the best red hardness properties. The best structure is the finest grained complete austenite, which results from a minimum time at the lowest temperature that will give this complete transformation. Under the microscope, properly etched samples of hardened specimens will show a distinct net work of polyhedral grains at a magnification of 500. Overheating or a little longer time at the high heat than is required greatly coarsens this structure. By making a brinell impression on a polished specimen, the metallographic test can be checked. The over heated coarser grained samples will show minute star-like cracks around the brinell impression.

It is absolutely necessary to have a standardization test of this kind, which should, of course, be supplemented with a fracture test, and if possible by an actual work test in order to be able to control the many variables that affect the steel and its heat treatment. The size of the piece being hardened and its relation to the size of the furnace, the heat capacity of the furnace and the cooling effect of putting in the work, the initial temperature of the piece when it is placed in the high heat chamber; the nature, temperature and location of the quenching bath: the condition of the pyrometer and the relation of the temperature of the fire end to the heating tool are all vitally important considerations. It is evidently impossible to describe the heat treatment of a certain tool by stating that it was heated to 2250 degrees Fahr., quenched in oil and drawn to 1150 degrees Fahr.; for even if the hardener did exactly that, he could ruin the best high speed steel tool if his furnace atmosphere was too oxidizing; or if the piece was left in the furnace longer than necessary. In order to standardize treatments it is necessary to standardize and control all the working conditions.

The possibilities of the salt bath method has always interested the speaker very much in this connection, for it gives an opportunity of getting real equilibrium between the heating medium, the fire end, and the pieces being treated, that cannot be attained in any other way. In a muffle-type furnace or in packed work, there is always a variation of temperature in the different sections of the furnace or of sections of the tool in the furnace. This is a broad statement; but a study of the different times it requires to get the fire end to indicate the best average temperature of the different sections of a furnace, the length of time required to get a true reading, leaving a massive tool in long enough to get actually uniformly heated to the average temperature of the furnace, it will be found that it is practically impossible to get real equilibrium in such a furnace. The practical solution of this difficulty is, of course, to have the furnace hotter than the work, and only leave the work in for the shortest time required to harden the cutting sections. This

is only a compromise method and incapable of giving consistent, uniform results.

A very small piece in a very large furnace will come nearest to giving a satisfactory flow of heat into the steel, but unfortunately such a relation rarely occurs in shop work. In a liquid medium of fused salts this difficulty is overcome. A lower furnace temperature can be maintained with a liquid medium; for, as explained above, the temperature prescribed for hardening in the muffle furnace or in pack hardening, is the temperature indicated by a fire end fixed in the furnace; not the temperature given the tool after the shortest possible time necessary for hardening in the open fire; or the temperature of pieces in the center of the pot packed with heat insulating material in back hardening. In a liquid medium as of fused salts, equilibrium can be obtained between the heating medium, the fire end, and the tool with absolutely no danger of scaling or overheating of small sections. The same heat can be given the tool at an apparently lower temperature because the heat stored in the bath flows uniformly into the steel instead of being pumped in at points of solid contact or by radiation through an oxidizing and poorly conducting gas.

It is rather general practice now to quench high speed tools in molten salt or lead at about 1100 degrees Fahr. though some shops still quench in oil and draw back to 1100 degrees Fahr. The former method minimizes the danger of cracking and still gives the advantage of increased performance by developing the secondary hardness properties. The flow of heat from the tool into the quenching medium should be uniform and this is obviously not possible with water or oils that vaporize in contact with the heated piece.

In quenching, the rate at which the steel cools through the few degrees of its critical range determines the completeness of the change of structure or the success of the hardening. This rate of cooling depends on the quenching medium, its temperature, the temperature of the steel being hardened as it enters the quench, the mass or size of the steel and of the quenching bath. If pieces are very small, and the quenching bath large, by proper agitation a very rapid cooling will occur and extreme hardness result. If such pieces were heated hotter than necessary for complete transformation the effect would be to retard the rate of cooling through the critical range with resulting loss in hardness and also brittleness from grain growth. The nature of the medium, its heat capacity or ability to absorb heat is of fundamental importance.

The fact that small pieces of high speed steel can be hardened when quenched at temperatures as high as 1250 degrees Fahr., shows how much more important is the heat capacity and fluidity of quenching medium than the actual temperature of the quenching medium. The fact that molten salts are stable at these temperatures, and are not volatilized by the contact with the heated piece, make them more dependable for quenching high speed tools than oils or other liquids of lower boiling points.

When the heating has to be done in an open fire or muffle furnace it is highly desirable to have the fuel regulated so that there is a minimum proportion of air, and therefore of oxygen, burning with the fuel when the tools are actually in the fire, in order that the scaling will be minimized. Great care also must be taken to leave tools in for the shortest possible time for the same reason. The time at the high heat can be minimized by making the preheating as thorough as possible.

A great many failures that the hardener cannot help are blamed on heat treating and many times bad steel is blamed for a poor heat treating job. As a matter of fact, the heat treater to be successful has to be a well tempered individual and be willing to go more than half way to overcome troubles. It has been shown that there are over 200 possible reasons why a high speed tool may fail, and the heat treater only directly controls about 10 of these reasons. However, he can modify his treatment and often make faulty steel do passable work.

There is considerable interest being shown at present in the possibilities of cast high speed steel tools. The advantage of eliminating waste in machining, especially in very large form cutters, is obvious, but it has not yet been well established that annealing and heat treatment can give the refinement of grain that is obtained from the rolling and hot working of tools made from bar stock.

For high speed tool work some nonferrous alloys have been developed, mostly alloys of cobalt with metals of the chromium group. These can be used very satisfactorily on certain classes of work, particularly on very hard material and where fine finishing cuts are not necessary. These alloys cannot be machined or heat treated thus tools cast from them have to be ground to shape, and since they are more brittle than high speed steel tools their application is further limited.

CARBURIZING, HARDENING AND TEMPERING HIGH CARBON ALLOY STEELS IN 130 MINUTES

By R. L. Gilman*

(A Paper Presented at the Philadelphia Convention)

Metallurgy, mechanics, and economics should be so correlated that more efficient, more rapid, and more economical production may be obtained. This article refers to a typical complete set of heat treatments for small hot or cold shaped objects of high carbon alloy steels, especially chrome-vanadium alloys, requiring maximum hardness and strength and above all the greatest possible uniformity of both. It is assumed that the stock has been thoroughly annealed previous to working. All statements to follow are based upon practice that has passed the experimental stage.

In speaking of carburizing eutectoid or hyper-eutectoid steels the author is aware that he may be charged with various errors in observation and fallacies in reasoning. Such a hypothesis, however, is permissible on condition that the very hard case produced is not detrimental to the product. It saves labor and time in subsequent operations and is a great aid in securing uniformity of surface hardness and finish. To those whose product will permit such use of the process it may be said that it "hides a multitude of sins," and in addition to hiding them compensates for some of them to a gratifying degree. Having carburized his work one may forget about unavoidable variations in carbon content and decarbonization of stock, and may proceed with precision and speed that will pay amply for the carburization; obtaining a product that is of superior quality by virtue of its uniformity, if for no other reason. Such carburization need not involve a separate heating operation, but may be combined with the high heating that is commonly employed to relieve

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strains of distortion and to promote refinement of coarse structure imparted by annealing the stock.

The 130 minutes includes all time during which a load of 130 pounds of steel is subjected to treatment in heating, carburizing, reheating for hardening, and in tempering operations. Of this time 120 minutes are spent in the carburizing furnace, about 7 minutes in the hardening furnace, and the remaining 3 minutes in the tempering furnace.

The work is handled once only in the entire process, that being in the operation of charging the carburizer. Quenching and conveyance from furnace to furnace and feeding the furnaces are functions of gravitation and mechanics and do not enter into consideration as time or labor consuming operations.

All furnaces are of the gas-fired rotary type automatically controlled within 10 degrees. This equipment gives precision and uniformity in the essential factors of treatment, feed, length of treatment or speed, and temperature. This uniformity is an important time saving feature of the process, rendering possible the use of high temperatures that it would be absurd to use in any other type of furnace. The author hopes some time to try electric rotary furnaces for such work. The electric furnace may be better insulated thermally than the gas furnace, simpler in construction, and may be installed where gas is not available.

The following method of carburizing gives excellent results on a very short treatment. The carburizer is charged at 1602 degrees Fahr. or higher, a small amount of gas is admitted to the retort to expel or consume the oxygen present, and maximum heat is applied automatically. The mass of the work insures slow heating, and the tumbling insures uniform heating of the pieces. At the end of one-half hour, when the work has assumed a low red heat a continuous supply of gas is allowed to flow through the retort. At the end of 2 hours from the time of charging, the work is dumped into oil where it remains only a few seconds, being brought out of the tank by an endless chain of buckets while still at a smoking heat.

Before entering the hardening furnace the work passes through a tank of boiling hot soda solution to remove the small amount of oil that may still adhere to it and to insure entrance into the hardening furnace at a uniform temperature, which is very essential in view of the mechanical nature of the process.

The hardening furnace is operated at some fixed temperature far above the critical range of the work, usually between 1600 and 1740 degrees Fahr., depending upon the size of the pieces of work and the rate at which they are fed through the furnace. Feed and speed of the furnace may be so regulated that the work will drop out at any desired temperature, the exact determination of which requires an optical pyrometer. It is well to pass a few pounds of scrap work or an equivalent run through the furnace immediately in front of and immediately after the work; other wise a small quantity of work will be overheated at the beginning and end of operations, or whenever for any reason the supply of work for the furnace is interrupted.

The use of the high temperatures just mentioned is conditional upon the size and shape of the pieces being treated. Pieces irregular in size or shape, or having thin spots or projections cannot be handled in this way for obvious reason. However, the high temperature is a great time saver and may be used safely upon objects of suitable size and shape. The

saving in time is not a result of forced heating, at least at the lower temperature, but is due more precisely to the elimination of the flat top of the temperature curve. The work is quenched in any suitable quenching medium, removed from the tank by an endless chain of buckets and fed mechanically into the tempering furnace.

The tempering furnace is of the same type as the hardening furnace, and likewise operated at a higher heat than the work can be allowed to reach. As the work falls from this furnace, it is allowed to accumulate in large boxes where its mass insures slow cooling.

The quenching mediums already referred to are cooled by circulation through a suitable external cooling system, and are delivered after cooling directly into the hoppers with the work. Brine pipes in these tanks would be of little use without changes in the equipment provided for receiving the work and carrying it through the tanks. A close inspection of the work after each quenching operation is maintained. This discloses the source of any trouble and usually suggests proper remedial or compensating adjustment of equipment or process.

No grave fears should be entertained regarding the rapid heating of this method, which is far more apparent than real. The load in the carburizer does not reach its critical point, below 1400 degrees Fahr. for more than one-half hour from time of charging, and it does not reach maximum heat for an hour thereafter. This is true regarding either a mass of work or individual pieces. A sort of tapered heat is maintained in the hardening furnace by the constant stream of work entering at a temperature of over 200 degrees Fahr. and rising in temperature as it moves forward. Each piece of work is subjected individually to a gradually rising heat for about 3 minutes, then to a nearly constant heat for about 3 minutes and finally to a gradually decreasing heat for about 1 minute. During this last minute the temperature of the work does not actually fall because it has never risen to the maximum heat of the furnace. This decline in furnace heat gives the work a chance to assume a more uniform internal temperature than would otherwise be possible. In the tempering furnace the conditions are similar to the conditions in the hardening furnace.

Regarding the results obtained by the method outlined the author can say only that they are as good as any he has seen. Since they equal the standards set for high grade bearings, certainly they will be found satisfactory for the majority of other pieces the size and shape of which will permit similar treatment. A true case of appreciable depth is easily shown to result from this treatment, but it is not apparent in the fracture unless the specimen is overheated or etched. It will be understood that this case does not differ much from the core in carbon content. There is no sharp line of demarkation between the case and the core. The case is too elastic to be clipped off. Under the hammer, test specimens never show any flaking or chipping, and often if not always, break internally before they do externally.

In the beginning of this article reference was made to the electric furnace as being desirable for installation where gas is not available. This refers to the use of a substitute for commercial gas as a carburizing agent. This substitute is carbon monoxide gas derived from limestone and charcoal. The author ventured upon the development of this subject and ventures to mention it now with timidity, well aware that such a promising method has probably been investigated from many angles and

rejected for good and sufficient reasons. Several methods of generating and applying this gas have been used with results varying from absolute failure to gratifying success.

This gas may be produced more economically than modern commercial gas and it possesses many advantages for the process just described. However, the details of preparation and application of this gas depend upon the results of further research.

The treatment just outlined does not in any way depend upon the outcome of the experiments last mentioned. In general, this method is admirably adapted to the case hardening of low carbon steels. In such an application, a somewhat longer carburizing time might be required; and an additional heating machine and tank might be needed for special treatment to regenerate the core after carburizing.

THE ROLE OF THE METALLURGICAL LABORATORY IN RELATION TO THE INSPECTION DEPARTMENT

By Earl W. Pierce*

(A Paper Presented by Title at Philadelphia Convention)

By pointing out the value of co-operation and the advantage of thorough and conscientious investigation, an effort will be made to show wherein the laboratory and the inspection department will be able to strengthen their positions in regard to quality production on a commercial basis. There are, no doubt, many instances that could be pointed out which would go to show the lack of co-operation between the inspection department and the metallurgical laboratory, but that would not be of an instructive nature and it is along constructive lines alone that this article will proceed. Therefore, this paper will be an effort to build up a working bond between these departments by which they best can work and agree to further the cause of quality and production.

The metallurgical laboratory as an asset to industries in the field of the metal trades rapidly is becoming recognized as such and making for itself a place which is indispensible in all respects. The position of the chemical laboratories as a requisite to industry has been established to such an extent that it no longer lies in a questionable field as to the advantages thereby derived. It is now time that the metallurgical laboratory must make its mark and continue to do so to hold the position it has attained.

There is no doubt that the recent development in this field owes its source to the demands brought forth on it by the late war. It was then that metallurgists and the practical heat treater were in demand to solve these problems and produce the goods under existing conditions.

Various surveys were made and the methods of handling the work was recorded. It was a great surprise in many cases to find the inadequate and crude ways the work was handled. Many of these conditions were improved and great assistance was brought through the metallurgical laboratories to facilitate the method of production on a large scale which was then required. The credit for such good work was justly given to the metallurgist.

While we again are engaged in peacetime pursuits, the metallurgical laboratory must not rest on its oars and live on its war time achievements, but must rise to the problems of the greater production de-

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manded in the steel industry in this great period of reconstruction. It is universally conceded that the field of metallurgy is in its infancy, so to speak, and the greater developments are yet to come. Therefore, it must keep up its prestige and continue to prove itself capable and an asset to all good industrial methods by showing the constant advantages to be derived from unending research and investigation. The metallurgical laboratories must then be an investigating organization and a source of inspection.

Heat treating material and chemical testing of materials have all experienced phenominal growth. War production was the direct influence, and the success of our efforts in the industrial end of the war game was largely responsible for the success of the men in the laboratories. New metals have been invented or created. Special alloys used in the production of some of our war materials were hardly known a few years ago. The metallurgist today is continually looking for new methods or practices in order to find a better way to do a thing.

Present conditions in shop practice indicate the demand for heat treating equipment, chemical and metallurgical laboratories for the main purpose of insuring the product and adding efficiency to the organization. Various plants advertise that they have complete laboratories, thereby guaranteeing their product to the public.

It is thus recognized that the need of such equipment to take care of the increasing demands made on the manufacturer is essential. The metallurgist must proceed to prescribe the proper steels and the proper treatment. After the proper material is selected and the prescribed treatment is given, the material passes on to the final processing, and the degree of success with which it meets in this stage, alone is due to the inspection it receives.

The many types of alloy steel produced in the past year have given the engineer and metallurgist a much greater field from which to choose the materials best adapted to their requirements. It is necessary that the relation of cross section to physical properties be better understood in order that material of proper strength and of as light weight as possible may be selected. Investigation and experiment carried out along these lines has shown that an alloy steel of the milder type is of better quality.

The best steel of this type contains less than 1.0 per cent chromium in combination with about 3.0 per cent nickel and less for parts of 2-inch sections and under. However, the chrome-molybdenum type is now being given greater preference. By the use of such alloy steels, the cost of production alone is reduced by the advantage in the use of smaller section. It is ncessary that these mild steels be selected with care and be subjected to rigid inspection to insure material that has been well made and of the proper physical requirements. Exacting inspection will prove of profit in this particular.

Complete specifications should be made out by the engineering and metallurgical departments showing material requirements, method of procedure and inspection specifications. In this way a standard product can be insured and the metallurgical and inspection departments working together can maintain this standard. It is often the case to find the laboratory under the jurisdiction of the inspection department, but this is only another means of showing the interdependence they must have.

To accomplish the greatest results, the metallurgical laboratory must become an inspection department and work as such in co-operation with the general inspection department. It is absolutely necessary in any industrial organization to maintain the standard and possibly to be a little bit better than the standard. The method of handling this work must then be efficient and thorough in order that finest quality may be assured. Quality, then, must be the first aim from a metallurgical standpoint, and must be insured by the inspection department. Here direct co-operation with the metallurgical laboratory must be evident.

The work in question should be submitted to the laboratory for investigation and the mode of inspection can thus be determined from the results obtained. Instructions can be given to the inspection department to proceed in a manner with testing in accordance with the requirements of the particular work concerned.

It has very often been the case that a certain course of inspection has been prescribed entirely unfitted to the later requirements which the part must meet in service. If the metallurgical department were not co-operating with the inspection department it would not take long for a sufficient number of these parts to get in service and cause the company an unlimited amount of trouble in adjusting such mistakes. There is also the other side, that where the inspection is inadequate. A large amount of work which has been properly heat treated will be rejected to a salvage department where a considerable quantity of perfectly good work may be scrapped unknowingly.

The proper inspection must be decided upon, which includes tests of the following nature; file, sclerescope, brinell and physical, both static and dynamic. It is needless to go into detail concerning these tests but it is sufficient to say that the file may be used with considerable accuracy on certain kinds of work such as cyanide work and case hardened work requiring a hard wearing surface, but where no physical strain will come, and as a comparative test only. It is well to say here that there is a great field for improving instruments or perfecting new ones to measure the relative hardness of metals. The sclerescope test is a much more accurate measure of hardness than a file although it has its faults. The brinell test is a more practical test when possible.

Inspection of case hardened parts by fracture of several parts in each heat will be of great advantage in determining the general characteristics of the kind of work produced. This will give an insight to the quality of heat treatment and will often tell a story which could not be known otherwise. This sort of a test should be left to the laboratory entirely and should be in the hands of a competent man so that any defects can readily be looked into and remedied at once. It is very often the case that this kind of a test is left to an inspector who has no knowledge of what he is doing and therefore has rendered no service whatsoever having only added to the scrap pile.

Physical tests of a static and dynamic nature must be left to the laboratory and are tests which are of more value than the others and determine the strength and brittleness of the parts.

Proper inspection of material from the receiving of the rolled stock until the last processing is essential to good heat treating. The stock when received, if properly inspected for seams and other injurious properties such as piping and segregation, will relieve many troubles in the heat

treatment. It is very often the case that cracks found in forgings after hardening are charged to the heat treater when it is simply a case of neglecting to reject such stock in the first inspection. By keeping strict record of work produced in the heat treating department by submitting a certain amount of samples to the laboratory for examination,—these samples always being taken from parts in regular production—the inspection department can be of great service to the metallurgist in maintaining a check on the finished product.

After the material has left the heat treating department and is delivered on the machine shop floor, the relation of the metallurgist to the inspection department does not need to cease, as often heat treated work may have passed inspection and still give trouble in machining. When such troubles arise it is well for the inspector to report such difficulties to the laboratory so that due investigation may be given the matter and the trouble determined.

It is then a question of knowing the machining qualities of the steel with which you are working and to know the hardness at which it will give the least difficulty possible and still retain the physical properties which are absolutely necessary. Very often in such a case the trouble may be found in improperly hardened tools or still more, properly hardened tools but not properly tempered ones.

To determine when tools and especially high speed tools, are of the proper hardness requires also some experimenting and a knowledge of the grade of steel used in the tool, as at the present time there are so many grades of high speed tools on the market with practically no two of the same characteristics. This then goes to show that the inspection department by working with the laboratory in such matters, can save a great amount in time and labor by calling a man who is familiar with such cases and can then adjust the treatment of the steel to more satisfactory processing.

There is one thing that must be watched in machine shop troubles and that is in ordinary times of production the machine is set for certain speeds and feeds to take care of the hardness of the steel as it comes when treated in the regular manner which however may be a little high for rapid work but still well within the limits of good machine shop practice. An order comes to speed up production and, as you would expect, the cry comes that the stock is too hard and that the heat treatment is at fault. The cause is very evident and it is only a case of inspection to show the existing hardness and as is usually the case, the material is found to be of correct hardness. It is simply a case of adjusting the machine for the object desired.

In the case of failures of parts due to unknown causes, all such defective parts should be turned over to the laboratory to determine, if possible, the cause and to remedy any methods which tend to bring about such failures. Very often such causes occur from segregation of impurities, blow holes and piping in the original stock. Again such failures may be due to cold shorts, burning and pitting in the process of forging and heat treating. In every case, however, it is essential that the inspection department inform the laboratory of such cases and submit the faulty pieces for examination. In these cases the laboratory only is equipped to handle such work and in such work the microscope proves itself invaluable.

The difficulties experienced in grinding case hardened parts present problems which are not easy to solve without some investigation. Grinding checks are of very common occurrence and more often progress beyond the stage of checks and become case lifting. It is very common practice to put the blame of such work on to the case hardener and say it is caused in the treatment. The author is not of this opinion and believes that a great majority of this trouble can be traced to improper grinding which is directly caused by rushing the work in an effort to increase production, especially where the work is on a piece-work basis.

Such troubles when noted should be brought to the attention of the metallurgist and should be investigated and if hardening operations are inadequate to take care of the part in question, a change can be made to eliminate or greatly lessen the trouble. However, it is well to look into the various grinding conditions as very often the seat of the trouble is a lack of good grinding knowledge in regard to the kind of wheel to use and also the right speed. Faulty use of the grinding medium is a very common cause as well as the lack of frequent wheel dressing.

As the various tests which should be made on heat treated and case hardened steels for the best quality are so distributed between the metallurgical laboratory and the inspection department, it is absolutely necessary that one supplement the other and co-operate to the common good of all concerned. In this way can quality and production be linked together, and in the end, production must be maintained and not held up. It is in the fact that the laboratory, through the aid and co-operation of the inspection department, can produce quality and not hinder production, that it will make its strongest stand.

EDUCATIONAL CO-OPERATION

In April last year F. C. Lau, of the Chicago Chapter and since last May its chairman, proposed that an effort be made to induce at least two of the technical schools of Chicago to offer evening courses in the forging and heat treatment of steel. After a tentative plan had been prepared and after Mr. Lau had become chairman of the Chapter an Educational Committee of three, consisting of T. E. Barker, chairman; E. J. Janitzky and C. P. Berg, was appointed with power to act for the Chapter in such dealings as it might consider desirable with such educational institutions as would seem likely to serve the community beneficially in offernig the courses which were proposed.

Here is published the experiences of this committee and the schools and the results attained by their activities, believing that the information may be helpful to other chapters which may find similar movements in their communities desirable.

The first move by the committee was to state its proposition to the Deans of the Armour Institute of Technology and the Lewis Institute both of whom felt kindly toward the scheme but were at a loss for available talent in their faculties to handle such classes. The committee then proposed that instructors be furnished from the membership of the Chicago Chapter, that is, technically trained men professionally employed in the practical work at local industries. This was approved by the Institutes and from that day to the present the Educational Committee has been a very busy one.

The tentative plan, which became the final plan, was to embrace the following subjects in the course:

Pyrometry
Metallography
Forging (Effects on Structure)
Annealing
Alloy Steels
Hardening and Tempering Tool Steels
Case Hardening

Volunteers were called for in open meeting and by mail and a generous response was received. Subcommittees of three each were appointed to select and prepare texts for each of the subjects of the course, as outlined above, and present them to the classes.

Claude S. Gordon of Claude S. Gordon & Co., accepted the chairmanship of subcommittee on "pyrometry."

R. W. Burleigh, metallurgist, U. S. Ball Bearing Co., took the chairmanship of the "Metallography" subcommittee.

F. C. Lau, secretary, Arrow Forge & Tool Works and Chairman of the Chicago Chapter was chairman of the subcommittee on "Forging."

William Finkl, metallurgist, A. Finkl & Sons Co., with his committee handled the subject of "Annealing."

The subject of "Alloy Steels" was handled by E. S. Brown, metallurgist, Miehle Printing Press & Mfg. Co., and his committee.

Harry Blumberg, metallurgist, Illinois Steel Co., served as Chairman of the subcommittee which handled the subject "Hardening and Tempering Tool Steels".

"Case Hardening" was handled by a committee of which T. G. Selleck, the well known authority on that subject, was chairman.

Of course, it will be realized that a detailed study of all of the above phases of heat treating could not be encompassed in the brief time of 20 evenings which is the usual term of evening courses in these Institutes, nor was this the object of this first course. Its purpose was to give to these classes, composed of hardening room workers and students, a broad vision of the science and a comprehension of the possibilities in the steel treating field. In other words, this course was calculated to create a desire for a more thorough understanding of each of the several scientific phases of the art, each of which are to be specialized upon by classes which will follow.

Before these classes were organized conditions had changed in the staffs of the Institutes mentioned and the Armour Institute had available for instructing in this course, Prof. Arthur Howe Carpenter, thus relieving the educational committees of the Chapter the tasks of presenting the subject to the classes.

Professor Carpenter, because of the previous education and experience of the members of his class, concluded that he could best serve by devoting the entire term to the metallographic study of structural changes due to heat treatment and proceeded along that line.

The Lewis Institute, a few months previous to the starting of its two classes, of about 20 each, added to its faculty Prof. John F. Keller, former-

ly professor of forging of Purdue University, Lafayette, Ind., and past president of the Steel Treating Research Society, who took charge of the forging and heat treating instruction.

Professor Keller, however, preferred to conduct the work along the plans proposed by the educational committee and in presenting the course to the classes to avail himself of the assistance of those who had prepared the texts and lectures.

Both Institutes, while possessing considerable apparatus and equipment necessary for the successful presentation of the subjects, made liberal expenditures to make their facilities complete, this outlay amounting to several thousand dollars.

Classes were started with a motion picture lecture, illustrating all phases of steel manufacture from the mining of the ore to the finished bar, this serving to arouse a keen interest in the minds of the students for that which followed.

The evolution of the popular types of pyrometers and the fundamental principles of them were thoroughly explained by lectures, lantern slides, demonstrations and by competent and comprehensive answers to class questions which brought out much of value in the nature of practical self helps in every day practice.

The microscope, its manipulation and application, together with the methods of preparing specimens was next treated by lecture, illustrations and demonstrations, which, while only scratching the surface of the subject, was a revelation to most of the students and gave them a vision of the possibilities in the study and development of the heat treating art, to which a thorough knowledge of metallography would contribute.

Instructions in the use of the pyrometer and microscope were first in the course because of almost constant reference to them in the lectures and demonstrations pertaining to the subjects which followed.

Forging was made very interesting to the classes by running two furnaces side by side on specimens of the same material one with proper heats, the other with improper heats, after which the difference in results was observed by microscope and physical tests. High heating and soaking with but little work, producing extreme grain growth; rapid heating and working over a cold core, developing slip bands and surface cracks; conversely the results of forging on a falling temperature after a high soaking heat, thus producing internal cracks and pipe; varying grain structures produced by uneven heats were also illustrated. The action and effect of sulphides and phosphides when excessive heats and light forging is done, especially when the finishing is done at a temperature above normal for forging, was clearly portrayed by specimens and micrographic slides. The baneful results of improper upsetting, edging up and cold bending were made evident by the shear lines, cracks and slip bands in samples thus mistreated.

Following the lectures and text on forging came the treatment of annealing which was considered from all angles. One feature of this deserves special mention, namely, the demonstration of the fallacy of the idea, held by some, that annealing is a "cure-all" for all the diseases in steel inherited from faulty forging.

The effects of alloys in steels was handled in a way to impress upon the student's mind the function of each of the commonly used elements and

the physical characteristics produced by varying amounts and combinations of them. Also their influences upon the critical temperature ranges as contrasted with the regular carbon diagram were demonstrated.

High carbon and high speed steels were treated by a separate text, supplemented by slides and the microscope, the same scheme of treating and mistreating samples being resorted to to carry the points home to the student.

Last, but not least interestingly and thoroughly handled was the subject of case carburizing and hardening. This was accomplished by a large collection of specimens, lectures, charts, slides, micrographs and practical packing and heating demonstrations.

Enthusiasm was maintained throughout the course and all who participated voted it a great success, many expressing themselves as having been benefited far more than they had any anticipation when they entered.

Success of the course is assigned to the co-operation of various committees and those who offered helpful suggestions while the lectures were being conducted. The success was made more complete through the generosity of several steel companies which supplied samples of their analyses and other data of value.

HOW THE PHILADELPHIA CHAPTER CONDUCTED A SUCCESSFUL MEMBERSHIP CAMPAIGN

By H. C. Knerr*

In April, 1920 the chairman of the Philadelphia Chapter received a letter from the national headquarters containing information regarding the convention to be held in Philadelphia in September and suggesting that the local chapter conduct a membership campaign for two or three hundred new members before the convention. Thus spurred to activity and since the summer months offered excellent opportunity for such work, the membership committee decided to organize a campaign.

When the committee was completely organized, one of the problems that confronted it was how to get the entire membership to work. Without the support of all those who had evinced sufficient interest to pay their dues, any campaign would have been fruitless. The first step was to divide the city and adjacent territory into five sections. Following this the available membership was divided into five groups and each placed under the leadership of an active member with an associate member as an aide. The out-of-town members and the chapter officers composed a sixth team which was responsible for all outlying territory. A bulletin was issued and sent to every member explaining the purpose and plan of the campaign. Prizes were offered for the highest and second highest individual score.

It was soon found, however, that the team plan, although plausible in theory, was cumbersome and ineffectual for several reasons. Team captains found great difficulty in maintaining contact with the members of their teams and in helping their teams work as a whole. Some of the team captains found it impossible to devote the necessary time to the work and canvassing of a specific territory by members of a team proved to be

* Metallurgist, Naval Aircraft Factory, United States Navy Yard, Philadelphia, and chairman Philadelphia Chapter membership committee.

impracticable. Individual activity of the members independent of any rules or regulations proved to be the most fruitful of results. Therefore the team plan was discarded.

At chapter meetings the scores of individual members were posted on the blackboard. This enlivened interest in the campaign and promoted a friendly and resultful spirit of competition. At intervals, letters were sent to all members reporting progress of the campaign and offering suggestions for greater results. One of these letters which proved specially effective is given below:

December 7, 1920

Dear Fellow-Member:

We have just received a definite statement from Headquarters that the Initiation Fee is waived until January 1, 1921—*only*.

This means that those who have, for diverse reasons, postponed sending in their applications for membership, and those with whom you have not as yet gotten in touch in regard to joining, will profit to the extent of $3.00 for regular members, and $10.00 for associates—real money—if they act at once—NOW.

We ask you to make this clear to all prospective members whom you have in view. The time is short. The holidays coming at the end of the month will make it shorter. (In case spare cash is also short, remember that a deposit of only $2.00 is required.) DO IT NOW.

Applications may be mailed direct to the writer, or to Mr. A. L. Collins, Engineers' Club, 1317 Spruce St,. Philadelphia. Checks should be made payable to Arthur L. Collins.

Have you enough Application Blanks?

Special: A personal chat is the surest and best way to interest a new member. But if there are some good "prospects" whom you cannot reach personally, please put their names on the enclosed return postcard and mail it without delay; also, if possible, send each of them a note, or phone him, telling him of your action.

We will write each man a letter, stating that you have recommended him for membership, explaining briefly the advantages, and inviting him to join. You will be credited with any applications so received.

If you think of more "prospects" later, send another postal. Thank you.

H. C. KNERR,
Chairman, Membership Committee, A. S. S. T.
Engineers' Club of Philadelphia,
1317 Spruce St,
Philadelphia, Pa.

Personally addressed letters were sent to all prospects as they were proposed and recommended by the members. This letter was as follows:

.....
.....

Dear Sir:

One of our members, Mr. ..... has recommended you for membership in the American Society for Steel Treating, and at his suggestion we take pleasure in sending you information concerning the Society and inviting you to apply for membership.

As one whose work deals with the use of steel, or with some of the many phases of its treatment, you will naturally be interested in the activities of this organization.

The American Society for Steel Treating is a new national society, created by the amalgamation of two former bodies, the Steel Treaters Research Society and the American Steel Treaters Society. Its formation is a result of the general awakening to the tremendous industrial importance of more comprehensive and accurate knowledge concerning the treatment of steel.

The purpose of the Society is educational, and includes the collection and dissemination of knowledge concerning the heat treatment of steel in its diverse forms and bearing upon processes, instruments, equipment, and methods employed in the art. A special aim is to closely unite those engaged in the practical, technical, and theoretical branches of the work.

There are now about thirty Chapters in the leading cities of the United States, and the membership is rapidly growing.

The Philadelphia Chapter holds monthly meetings at the Engineers' Club of Philadelphia, with which body it is affiliated. Papers are read, frequently illustrated by lantern slides or motion pictures and are followed by questions and discussion.

The best papers presented at the various Chapters are published in the monthly "TRANSACTIONS" of the Society, thereby keeping all members in touch with the latest advancements of the Art.

Membership in the Society (Philadelphia Chapter) includes:

(a) Identification with the only National Organization devoted solely to the Treatment of Steel.
(b) Subscription to the Transactions ($15.00 per year to nonmembers.)
(c) Free use of Employment Service Bureau.
(d) Attendance at the monthly meetings of the Philadelphia Chapter at Engineers' Club, 1317 Spruce St. Participation in papers and discussion. (Membership may be transferred to any other Chapter).
(e) Affiliation with the Engineers' Club, conveying privileges of the Club on meeting nights.
(f) Subscription to the Journal of the Engineers' Club of Philadelphia ($4.00 per year to nonmembers). (A progressive and valuable publication).

The dues, including all the above items are:

Member	$10.00	per annum
Associate	15.00	per annum
Sustaining Member	25.00	per annum

Initiation Fee (Waived until Jan. 1, 1921)

Member	3.00
Associate	10.00

See application blank for classification of membership.

An application blank is enclosed. We shall be glad to provide the necessary endorsement if you will fill out the form and mail it to the undersigned. Needless to say, this invitation is in itself a guarantee of favorable action by the Executive Committee upon your application.

IMPORTANT

The initiation fee is waived only until Jan. 1, 1921. The time is short. We cannot insure you the advantage of this saving unless favored with your prompt reply. A deposit of $2.00 should accompany application, or if you prefer, you may remit the full amount of your dues. Make check payable to Arthur L. Collins.

We hope to have the pleasure of welcoming you into the Society, and are confident that your membership would be a benefit both to yourself and to us. Trusting to have your early and favorable reply, we are

Yours very truly,
American Society for Steel Treating
Philadelphia Chapter
per .....
Secretary-Treasurer,
1317 Spruce St., Phila.

The results of the campaign which was carried on until the March meeting of the chapter were as follows:

Old members on June 1920	57
Steel Treating Research Society members at time of convention	26
New members obtained up to March 24, 1921	152
Total members on March 24, 1921	235

The contest for the prizes was closed on Dec. 31, 1920, at which time the highest scores were as follows:

	New Members	
H. J. Huester	13	First Prize $10.00
G. W. Tall	8	
G. P. Bible	8	

E. J. Gaugham	8	Second Prize $ 5.00
H C. Knerr, Chairman	25	

Second prize was awarded to Mr. Gaugham through the withdrawal of Mr. Tall and Mr. Bible on the ground that they were associate members and had greater opportunity for obtaining new members than Mr. Gaugham.

One feature of the campaign was that one man, an active member and chairman of the membership committee, who had little opportunity of getting out to meet new men, obtained 25 new members. The real success of the campaign was due largely to the co-operation of the committee and the untiring efforts of its chairman, H. C. Knerr.

THIRD ANNUAL CONVENTION OF THE AMERICAN SOCIETY FOR STEEL TREATING, STATE FAIR GROUNDS, INDIANAPOLIS, IND., SEPT. 19-24, 1921.

General Topics

1. The Organization and Management of a Heat Treating Department.
2. Practice of Handling and Checking Materials to and from Heat Treating Department.
3. Quantity Production Methods for Forging and Heat Treating Tools.
4. Methods for Heat Treating very small Machine Parts.
5. The Heat Treatment of Sheet Steel Parts as Saws, Hack Saw Blades, etc.
6. The Artificial Seasoning of Hardened Steel.
7. Furnace Design with Reference to Fuel Economy.
8. Metallography and its Applications.
9. Comparative Study of Methods for Heating Furnaces by (a) Coal, (b) Fuel Oil, (c) Gas, (d) Electricity.

Alloy Steels

1. Topical Discussion of Alloy Steels and their Heat Treatments for Specific Purposes, as (a) Springs, (b) Gears, (c) Finishing Tools, (d) High Speed Cutting Tools, (e) Dies.
2. Practice of Ordering Tool Steel on Specifications.
3. Cutting Efficiency of High Speed Steel Which Has Received Different Methods of Hardening.
4. Die Blocks and Their Heat Treatment.

Carburizing

1. Carburizing Practice Adapted to Alloy Steel Parts.
2. Determination of Unit Cost of Carburizing Steel Parts.
3. The Efficiencies of Different Mixtures for Cyanide Hardening.
4. Practice of Cyanide Hardening.
5. The Service of Annealing Boxes Made of Different Materials.

Notice Regarding Papers

Each member of the Society should consider it a duty to carefully consider the investigations which he has made with the thought of presenting at the Annual Convention any information which will be of interest to the members of the Society. There is no better way to fulfill the spirit of our motto: ALL FOR EACH AND EACH FOR ALL.

All papers for the Indianapolis Convention should be in the hands of the Committee on or before Aug. 1, 1921.

The Meetings and Papers Committee wishes to know the topic which you decide upon. It is not necessary that it be included in the attached list of topics.

This form is for your convenience. Please fill in the necessary information and mail today.

To Chair of Meetings and Papers Committee,
H. L. Campbell, 1103 E. Huron Street, Ann Arbor, Mich.

Name ..... Address.....

Firm connected with .....

Occupational capacity .....

Subject .....

Will your paper be illustrated by lantern slides? Yes..... No.....

Suggestions .....

.....

OBITUARY

Harold George Weidenthall

Harold George Weidenthal, metallurgical engineer, Cleveland, O., died on April 13. Mr. Weidenthal was born in Cleveland, March 16, 1891, was educated in the public schools, graduating from Lincoln High School in 1909 and Cornell University in 1913 with the degree of M. E. During vacations he worked at the Brown Hoisting Machinery Co., the Walworth Run Foundry Co., the Canton Rolling Mills and the Upson Nut Co. In 1913, after graduation, he went with The Lorain Steel Co., Lorain, O., as open-hearth foreman. In 1914 he joined the Upson Nut Co., Cleveland, as metallurgical engineer, leaving in 1915 to become connected with John R. Crowley Co., Detroit, as chief electric furnace melter. In 1916 he joined the Standard Chemical Co., Cannonsburg, Pa., as metallurgical engineer, but in 1917 became associated with the General Steel Co., Milwaukee, as works manager. From 1918 to 1920 he was with the James H. Herron Co., Cleveland, as vice president and chief metallurgical engineer. In 1920 he became consulting metallurgical engineer.

Mr. Weidenthal was a member of the Cleveland Engineering Society, the American Society for Testing Materials and the American Society for Steel Treating. He was a member of Board of Directors of latter society in 1919-1920.

News of the Chapters

NEW CHAPTER IN GARY

The steel interests of Gary have ever since the organization of the Society furnished a large number of members for the various local sections, and the idea was conceived by a number of the members that it would be advisable to have a local chapter established there that they might have monthly meetings and discuss problems of interest to all in the vicinity. Consequently, through the efforts of A. Hungelman, a petition of 21 signers was secured and presented to the Board of Directors asking that a chapter be granted to Gary. The application for a charter was favorably acted upon by the Board, and on March 14th a meeting of the signers was held and the following officers were elected:
Chairman—A. Hungelman, metallographist, Illinois Steel Co.
Vice Chairman—J. O. Lord, metallurgist, Illinois Steel Co.
Secy-Treas.—Carl I. Holm, metallurgist, Illinois Steel Co.
Boards of Directors:

1. W. E. Hadley, assistant general superintendent, Illinois Steel Co.
2. R. B. Lucas, superintendent wheel plant, Illinois Steel Co.
3. E. Hagadone, tool treater, wheel plant, Illinois Steel Co.
4. J. B. Monahan, superintendent rail mill, Illinois Steel Co.
5. C. J. Kennedy, engineer, American Bridge Co.

The first regular meeting was held on Wednesday, April 13, when W. H. Eisenman, National Secretary, was present and addressed those in attendance. About 125 were present at this meeting.

The excellent officers selected and the interest shown by the charter members is conclusive proof that Gary chapter has a bright and prosperous future.

ROCHESTER CHAPTER

W. B. Huther, president of the Huther Bros., Saw & Mfg. Co., gave a very interesting talk before the local chapter on the "Manufacture and Use of Saws", on April 1. Mr. Huther gave details of the various process used in making all kinds of saws, including machine work and heat treating. The meeting was held at the Rochester Hotel and was very well attended. A buffet lunch was served at the close of the meeting.

SYRACUSE CHAPTER

The local chapter held an extra meeting on March 29 at the Chamber of Commerce rooms which was addressed by C. U. Scott, president of the C. U. Scott Company, on the subject of "High Speed and Die Blocks". About 60 were in attendance and a very heated discussion followed the presentation of the paper.

BALTIMORE CHAPTER

The Baltimore chapter held a wide-awake meeting at the Engineers Club of Baltimore on Tuesday, April 19. G. W. Tall, of Leeds and Northrup Co., presented an illustrated paper on the "Hump Method of Heat Treatment". The meeting was well attended and most thoroughly enjoyed.

BOSTON CHAPTER

At the Engineers' Club, on April 12, Irving Cowdrey, instructor of mechanical engineering, Massachusetts Institute of Technology, and secretary of the local chapter, presented a paper before 50 of the members on "The What and Why of the Pyrometer". A very interesting discussion on the checking and calibration of pyrometers followed the presentation of the paper.

BUFFALO CHAPTER

C. U. Scott, president of the C. U. Scott Co., Rock Island, Ill., presented an interesting paper before the Buffalo chapter on Monday evening, March 28th, at the University Club. A dinner was served at 6:30 and the meeting at 8:00 was well attended.

DETROIT CHAPTER

On April 11, H. J. Stagg, assistant manager of Halcomb Steel Co., presented a very interesting paper before about 65 members of the local section in the Board of Commerce rooms. The paper was very well received and the members enjoyed the opportunity of meeting with Mr. Stagg, one of the National Board of Directors of the Society.

On April 28, C. M. Johnson, director of research, Park Works, Crucible Steel Co. of America, Pittsburgh, presented an interesting and instructive paper on "Resistal Steels". Mr. Johnson is thoroughly master of his subject and presented the paper in an entertaining manner. The evening proved to be very interesting and decidedly educational.

PROVIDENCE CHAPTER

On March 31 the Providence chapter of the Society had its meeting in the Providence Engineering Society rooms when Major A. E. Bellis, chief metallurgist of Springfield Armory, presented a paper on "Hardening, Quenching and Tempering of High Speed Steel". Over 80 were in attendance at this meeting and most thoroughly enjoyed Major Bellis' paper. An interesting discussion followed and was quite generally participated in by the members and guests present.

CLEVELAND CHAPTER

The Cleveland chapter has had the privilege of hearing very many prominent speakers throughout the year all of whom delivered excellent papers. Over 200 turned out Friday evening, April 22, in the Engineering Society rooms in the Statler Hotel, to honor Professor Albert Sauveur, professor of metallurgy and metallography at Harvard University. Pofessor Sauveur presented a paper on the "Dendritic Structure of Steel", which proved to contain the research done on this subject during the past two years at Harvard, and gave much interesting and enlightening information with reference to this peculiar structure. At this meeting Professor Sauveur was presented with his certificate of Honorary Membership in the Society.

CHICAGO CHAPTER

The Chicago chapter held its monthly meeting on Tuesday evening, April 12, at the City Club. Over 125 were present for dinner and for the meeting at eight o'clock, to welcome Lieut. Col. A. E. White, National President, who was guest of honor while paying his official visit to that chapter.

The meeting also served as a tribute to the first vice president of the Society, T. E. Barker, who is leaving Chicago to become associated with the Denver Rock Drill & Mfg. Co., Denver, Col. At the meeting, F. C. Lau, chairman of the local chapter, presented Mr. Barker with an electric percolator set, the gift of the members of the Chicago chapter to Mr. Barker. In Mr. Barker's response he reviewed the early history of the formation of the Society, inasmuch as he has been actively connected with it since the beginning of the Chicago chapter.

Col. White spoke impromptu on the work of the Society in general, and added his appreciation of the services of Mr. Barker in assisting in the development of the National Society.

The National Secretary, Mr. W. H. Eisenman, said a few words of Godspeed to Mr. Barker, and informed the other members of the chapter of the progress relative to the National Convention to be held in Indianapolis, Sept. 19 to 24.

Other speakers were: Mr. Nethercutt, secretary of the Western Society of Engineering; H. H. Clark, former chairman of the local chapter; Professor Keller, of Lewis Institute; A. G. Henry, first secretary of the local chapter and formerly National Secretary of the Society.

ST. LOUIS CHAPTER

Over 100 were present for dinner on April 11 at the American Hotel to greet the National president, Lieut. Col. A. E. White. The Colonel's visit was especially well received and the paper he presented was very interesting. The meeting proved to be most successful and enjoyable.

The regular March meeting was held at the American Hotel and was attended by about 75 members and guests. The speakers of the evening were G. S. Rogers, of E. F. Houghton Co., on the subject of "Quenching Mediums"; C. B. Swander, metallurgist for Wagner Electric Mfg. Co., and secretary of the St. Louis chapter, whose subject was "Hardening Drawing Dies". Walter Brown, of the Brown Tool Co., also spoke on the "Explanation of the S. A. E. Numbers".

WASHINGTON CHAPTER

Washington chapter had a very interesting and well attended meeting on Friday evening, April 22, in the auditorium of the New Interior Department Building, on the subject of "Molybdenum Steel."

The program was presented by two speakers. Dr. G. W. Sargent, president of the Molybdenum Corp. of America, spoke on "Some Features in Connection with the Development of Molybdenum Steel". Martin H. Schmid, metallurgist United Alloy Steel Co., Canton, O., spoke on "Molybdenum Steel and Its Application". Both speakers presented papers of interest and value to the designer, manufacturer, and user. An excellent discussion followed the presentation of the paper and the meeting proved to be very educational.

PITTSBURGH CHAPTER

The regular monthly meeting of the Pittsburgh chapter scheduled for Tuesday evening, April 19, was postponed due to the inability of Lieut. Col. White to be present. However, a joint meeting was held with the American Institute of Mining and Metallurgical Engineers at the Fort Pitt Hotel, on Wednesday evening, April 20. The speaker of the evening was Professor Albert Sauveur, who presented a paper on the "Dendritic Structure of Steel".

CINCINNATI CHAPTER

The April meeting of the Cincinnati chapter was held on April 1 at the Ohio Mechanics Institute, and was addressed by A. J. Wilson, of Warner Gear Co., Muncie, Ind., on the subject of "Making the Most Out of High Speed Steel". Over 75 were in attendance at this meeting and the discussion brought out by Mr. Wilson's paper was one of the most interesting that has ever been produced in this chapter. A buffet lunch at the close of the meeting served as a means of furthering the acquaintance of all the Cincinnati members.

On Friday evening, April 29th, at the R. K. LeBlond Machine Tool Co.'s plant, C. S. Gordon, consulting engineer, presented a paper on "Pyrometers and Their Application". Mr. Gordon is thoroughly familiar with this subject and his paper was well presented.

SCHENECTADY CHAPTER

The Schenectady chapter held its regular monthly meeting in the Civil Engineering Building of Union College on March 30 when C. U. Scott, president of the C. U. Scott Co., presented the paper of the evening, to over 75 members and guests in attendance.

Mr. George Smith, for several years considered the champion Indian Club swinger of Canada, presented an act of swinging illuminated clubs. Altogether the evening proved very enjoyable.

MILWAUKEE CHAPTER

The April meeting of the Milwaukee chapter was held at the Medford Hotel on April 14, when R. W. Burleigh, metallurgist of the U. S. Ball Bearing Co., presented a paper on "Some Fundamentals of Iron and Carbon Diagram". Some 65 members were in attendance and heard Mr. Burleigh's paper.

SPRINGFIELD CHAPTER

The April meeting of the Springfield chapter was held in the Chamber of Commerce Building on Friday evening, April 15. The speaker of the evening was Prof. John H. Nelson, metallurgist of Wyman-Gordon Co. Inasmuch as the Wyman-Gordon Co. is one of the largest producers of automobile crankshafts and it is Mr. Nelson's work to maintain their high standard because he is in control of the laboratory, the paper was, of course, very practical, interesting and instructive. The title was "The Forging and Heat Treating of Alloy Steels".

A question box was instituted at the last meeting by which questions relating to the subject of the previous meeting were submitted to the secretary and answered at the meeting on April 15.

LEHIGH VALLEY CHAPTER

Lehigh Valley chapter held one of its best meetings on April 26 in the Assembly Room of the Public Library of Easton. The paper was presented by W. R. Shimer, sales metallurgist of the Bethlehem Steel Co., who spoke on the "Manufacture of Steel from Raw Material to Finished Product". Mr. Shimer included in his paper, remarks on the heat treatment of steel and fatigue failure. The entire talk was illustrated by a number of illustrated slides. A nominating committee was appointed to nominate officers and executive committee for the following year.

HARTFORD CHAPTER

The April meeting of the Hartford chapter was held on the 14th at the Hartford Y. M. C. A. Assembly Room. The subject of the evening was of especial interest to all, and was presented by Lester Lanning, of the New Departure Mfg. Co., on "Open Hearth Furnaces", while C. B. Collingwood, superintendent of the Stanley Works, New Britain, Conn., spoke with reference to "Open Hearth Furnaces". The usual discussion on the elements and their effect on heat treatment was presented, the element vanadium occupying the center of attention. The discussion of shop problems was also continued. The committee appointed to consider the "Nomenclature of Heat Treating Terms" also reported.

NEW HAVEN CHAPTER

The New Haven chapter is fast making progress so that it soon will be recognized as one of the largest chapters in the East, not so much from a point of members, as from attendance at meetings.

Over 200 were present to see a practical demonstration made by Major A. E. Bellis, chief metallurgist at Springfield Armory, in hardening "High Speed Steel by the Salts Bath Method", in the heat treating department of the Geometric Tool Co. The use of the laboratory at the Geometric Tool Co. was obtained through the courtesy of Mr. Adt, president of this concern. The method demonstrated was similar to the one used at the Springfield Armory and deeply interested all technical and practical men. At the close of the demonstration, those present were the guests of the Geometric Tool Co., who presented some special moving pictures and very pleasing refreshments.

The second April meeting of the New Haven chapter was held in Waterbury at the plant of the Bristol Co., when W. H. Brown, president of the company, by the use of talking moving pictures, gave an illustrated talk on some of the latest pyrometer models and automatic pyrometer temperature regulators. In addition, Mr. Brown showed some of the latest developments in the field of talking moving pictures. Quite a large number of members from the surrounding towns and Waterbury particularly, were in attendance at this meeting.

INDIANAPOLIS CHAPTER

Indianapolis chapter had a very interesting meeting on April 12 when 75 were present at the meeting. A. L. Cramp, of Lafayette Motors, spoke on the subject of "Hardening Cam Shafts". W. R. Chapin, of E. C. Atkins Co., gave a talk on "Hardening High Speed". Both talks were very instructive and were followed by lively discussions.

The Nominating Committee reported at this meeting, selecting A. L. Cramp as chairman, and Paul Smith as secretary-treasurer. This report was accepted and election will be held at the May meeting.

The May meeting of the Indianapolis chapter was held in the Chamber of Commerce rooms on Monday, May 2. The annual election of officers took place at this meeting, after which, W. L. Patterson, of Bausch & Lomb Optical Co., gave a talk on "The Optics of Metallography". The talk was illustrated by lantern slides and proved very interesting and instructive to the large number present.

At a volunteer meeting of the members of the Indianapolis chapter for volunteers to serve on committees for the Convention, 75 local men responded and helped to get plans and activities under way to make the Convention a success.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ABBOT, R. R. (M-3), Met., Peerless Motor Car Co., Cleveland, Ohio.

ALLEN, R. D. (M-3), Asst. in physical testing Lab., Studebaker Corp., South Bend, Ind.

ANDERSON, Geo. R. (M-4), Fore., 1041 Goodlet Ave., Indianapolis, Ind.

ARNOLD, Mowry A. (M-3), G. M. C. Truck Co., Pontiac, Mich.

AURAND, Walter (M-2), R. Wallace & Sons Mfg. Co., Wallingford, Conn.

AUSTIN, J. H., Asst. Wks. Mgr., Goodman Mfg. Co., *for mail*, care company, 4834 S. Halstead St., Chicago, member, to April 1922.

BARACH, Samuel (M-3), Met., 1439 T. St., N. W., Tuxedo Apt. 308, Washington, D. C.

BARLOW, J. E., Inspector, Goodman Mfg. Co., *for mail*, 747 W. 55th Place, Chicago, Ill., member, to April 1922.

BARNETT, J. W. (A-3), Sales., Crucible Steel Co. of Amer., 1228 Callowhill St., Philadelphia, Pa.

BARRY, R. L., Engineering Dept., Goodman Mfg. Co., *for mail*, care company, 4834 S. Halstead St., member, to April 1922.

BECKER, Chas. R. (M-4), 631 Canton, Detroit, Mich.

BEGLEY, J. P., Chief Chemist, American Steel Foundries, *for mail*, 1448 East 72nd Place, Chicago, Ill., member, to March 1922.

BELL, Wm. H. (A-3), Sales, 2281 Scranton Rd., Cleveland, Ohio.

BERGGREEN, P. H. (M-5), Met., Room 281, Bureau of Mines, Pittsburgh, Pa.

BERLINER, J. F. T. (Jr.-3), Lab. Asst., 1471 Irving St., N. W., Washington, D. C.

BERRY, Geo. D., Inspector, International Harv. Co., Chicago, *for mail*, 6556 Cottage Grove Ave., Chicago, member, to March 1922.

BERRYMAN, H. H., Mach. Shop Foreman, Pheoll Mfg. Co., Chicago, Ill., *for mail*, as above, member, to April 1922.

BIHLMAN, Victor W. (M-3), Met., 36 Maple St., Springfield, Mass.

BJORSETH, K. E. (M-4), 10 W. Huron St., Chicago, Ill.

BLACKWOOD, Geo. E. (M-4), Tool Hardener, 8841 Monica, Detroit, Mich.

BODIN, George, Designer, Goodman Mfg. Co., *for mail*, 7916 S. Carpenter St., Chicago, member, to April 1922.

BRADFORD, J. F. (M-3), Sales., 1916 West Blvd., Cleveland, Ohio.

BROWN, James B. (M-3), 18 Washington St., Armour Park, S. Charleston, W. Va

BURROUGHS, J. T. (A-3), Sales., 3063 West Blvd., Cleveland, Ohio.

CASE, L. B. (M-3), 2261 Garland, Detroit, Mich.

CHAVEAS, Nicholas (M-3), Asst. Fore., 2264 N. 17th St., Philadelphia, Pa.

CHELIUS, E. J., Asst. Supt., Elec. Furnace Dept., Illinois Steel Co., *for mail*, Station No. 41, Illinois Steel Co., South Chicago, Ill., member, to April 1922.

COALE, J. D., Chief Inspector, Ingalls Shepard Division, Wyman Gordon Co., Harvey, Ill., *for mail*, 14608 Green St., Harvey, Illinois, member, to March 1922.

COPE, Lorenzo S. (M-2), 920 Mary St., Ann Arbor, Mich.

CRANE, Lewis Debb (M-4), Chem., 306 Waverly Ave., Syracuse, N. Y.

DARFLER, R. W., Asst. Foreman, Heat Treat. Dept., Ingalls Shep. Div., Wyman Gordon Co., Harvey, Ill., *for mail*, 209 Lewis Street, Blue Island, Ill., member, to March 1922.

DELAPOTTERIE, Harry (M-3), Eng., Falls Rivet Co., Kent, Ohio.

DERRY, A. T. (M-3), Asst. Phys., 3805 Yuma St., N. W., Washington, D. C.

DEVINE, H. A., Student, Lewis Institute, Chicago, *for mail,* 218 East 55th Place, Chicago, member, to March 1922.

DONALD, Gus, Chief Chemist, Ingalls Shepard, as above, *for mail,* 861 Summit Ave., Blue Island, Ill., member, to March 1922.

DUGRAY, F. S. (A-4), Res. Mgr., J. B. Ford Co., 603 Merchants Bk Bldg., Indianapolis, Ind.

DWALL, Henry (M-4), Care Weidley Motors Co., Georgia & Shelby Sts., Indianapolis, Ind.

EDSON, Charles S. (A-12), 4873 Edmonton, Detroit, Mich.

EMWECHTER, Norman (M-3), 512 Commerce St., Philadelphia, Pa.

EPSTEIN, Samuel (M-3), Asst. Phys., 925 North St., N. W., Washington, D. C.

ESSELTINE, A. B., Designer, Goodman Mfg. Co., *for mail,* 2026 N. California Ave., Chicago, member, to April 1922.

ETTER, Paul A. (M-3), 1736 Johnson St., Philadelphia, Pa.

EVERIST, L. E., Foreman Blacksmith, Goodman Mfg. Co., *for mail,* care company, 4834 S. Halstead St., Chicago, Ill., member, to April 1922.

FALLON, Thomas D. (M-3), Eng. of Tests, Camden Forge Co., Camden, N. J.

FARNSWORTH, Grover (M-3) Oakland Motor Car Co., Pontiac, Mich.

FINNERAN, E. J. (M-3), Naval Gun Factory, Washington, D. C.

FRANCE, Ramon D. (M13), Met., 405 M. Street, N. E., Washington, D. C.

GANCZ, Victor, Tool Room Foreman, Goodman Mfg. Co., *for mail,* 4512 N. Central Ave., Chicago, Ill., member, to April 1922.

GARDNER, Samuel L. (M-3), Insp. of Materials, 1335 C. Street, N. E., Washington, D. C.

GOETSCH, John R. (M-1), 226 Wells St., Wauwatosa, Wis.

GROH, Paul, Production Mgr., Pheoll Mfg. Co., *for mail,* care firm, 5700 Roosevelt Road, Chicago, Ill., member, to April 1922.

GRUDA, J. E. (M-4), Allis Chalmers Mfg. Co., West Allis, Wis.

HAMPP, Wm. (M-3), International Silver Co., Wallingford, Conn.

HANSON, G. A. (M-3), Mgr., 1636 South Broad St., Philadelphia, Pa.

HARS, David P. (A-4), Hotel Stevenson, 46 Davenport, Detroit, Mich.

HAWKINS, M. I. (M-3), Mech. Supt., Naval Aircraft Factory, Philadelphia, Pa.

HEASLETT, R. C. (M-4), Wheeling Mold & Foundry Co., Wheeling, W. Va.

HEISE, R. H. (M-3), Asst. Supt., General Metal Products Co., 2400 S. Jefferson Ave., St. Louis, Missouri.

HILLER, F. B. (M-4), 185 Fairview Place, Hartford, Conn.

HISLOP, Thos. W. Jr. (M-4), 2410 11th Ave., Watervliet, N. Y.

HORNER, W. C. (A-4), Sec. Treas. Deeds Commercial Laboratory, 2150 Montcalm St., Indianapolis, Ind.

HOGG, James M. (M-4), Crompton & Knowles Loom Works, Providence, R. I.

HOWLAND, J. A., V. P., A. O. Blaich Co., *for mail,* 635 Waveland Ave., Chicago, Ill., associate, to April 1922.

HURCOMB, F. A. (M-3), Plant No. 2 Studebaker Corp., South Bend, Ind.

HUTCHINGS, A. E., Inspector, Goodman Mfg. Co., *for mail,* 4138 Ellis Ave., Chicago, Ill., member, to April, to April 1922.

HYDE, F. R., Master Mechanic, Goodman Mfg. Co., *for mail,* care company, 4834 S. Halstead Street, Chicago, member, to April 1922.

IRVINE, A. S., Supt. Finishing Division, Ingalls Shepard Div., Wyman Gordon Co., Harvey, Illinois, *for mail,* care company, member, to March 1922.

JENKS, W. E. (M-3), Teacher, 2166 De Forest Rd., Cleveland, Ohio.

JOHNSON, H. A., Plant Engineer, Ingalls Shepard Division, Wyman Gordon Co., Harvey, Illinois, *for mail,* care company, member, to March 1922.

JOHNSTON, R. L. (M-3), Met., Acme Die Casting Corp., Bush Terminal Bldg., Brooklyn, N. Y.

JOHNSON, W. G. (M-3), Asst. Phys., 1811 Wyoming Ave., Apt. 32, Washington, D. C.

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KERSLAKE, R. E. (M-3), Met., Stop 7, Euclid, Ohio.

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KMAN, George, Foreman, Hardening Dept., Goodman Mfg. Co., *for mail,* 855 W. 51st Place., Chicago, Ill., member, to April 1922.

KOEHLER, W. W., Chemist, Goodman Mfg. Co., *for mail,* 3115 Osgood Street, Chicago, Ill., member, to April 1922.

KOKESCH, E., Division Supt., Goodman Mfg. Co., *for mail,* 8513 S. Morgan Street, Chicago, Ill., member, to April 1922.

KRYNITSKY, A. L. (M-3), Asst. Phys., P. O. Box 258, Mt. Ranier, Md.

LAMB, Lester S. (A-3), Sales., Halcomb Steel Co., 633 Arch Street, Philadelphia, Pa.

LARCHER, A. J., Asst. Supt., Ingalls Shepard Division, Wyman Gordon Co., Harvey, Illinois, *for mail,* 15235 Center Ave., Harvey, Illinois, member March 1922.

LIVINGSTON, Eddie (M-4), Hammersmith, 1208 S. 7th St., St. Louis, Missouri.

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MALONEY, Malcolm (Jr.-4), 120 10th St., Milwaukee, Wis.

MANCEL, J. J., Chief Inspector, International Harv. Co., Chicago, *for mail,* 416 W. 101st Place., Chicago, member, to March 1922.

MARTIN, L. A., Student, Lewis Institute, *for mail,* 218 East 55th Place, Chicago, Ill., member, to April 1922.

MAYER, C. W. (A-4), Mgr., 3532 Winthrop Ave., Indianapolis, Ind.

MCCADIE, J. H. (M-4), National Twist Drill & Tool Co., Detroit, Mich.

MCCULLOUGH, W. T., Chief Draftsman, Goodman Mfg. Co., *for mail,* 8112 Clyde Ave., Chicago, Ill., member, to April 1922.

MCKEE, W. GERARD (M-12), Asst. Met., Brown Lipe Chapin Co., Syracuse, N. Y.

MENGER, L. A. (M-4), LaFayette Motors Co., Indianapolis, Ind.

MIELKE, M. H., Asst. Foreman, Heat Treat. Dept., Ingalls Shep. Div., Wyman Gordon Co., Harvey, Ill., *for mail,* 590 Vermont St., Blue Island, Ill., member to March 1922.

MILLARD, F. G., Ingalls Shepard Division, Wyman Gordon Co., *for mail,* 15412 Center St., Harvey, Illinois, member, to March 1922.

MILLER, B. B. (M-3), 5821 Pennsylvania Ave., Detroit, Mich.

MILLER, H. B. (M-4), Fore., 236 Ricking St., Indianapolis, Ind.

MOHR, Edwin J. (M-1), 1903 Chambers St., Milwaukee, Wis.

MOORE, J. W. (A-4), 1404 Oliver Bldg., Pittsburgh, Pa.

MYERS, Lawrence E. (M-4), Prod. Clerk, 1441 W. 27th St., Indianapolis, Ind.

NAIR, F. N., Supt. Heat Treating and Cold Drawing Dept., Interstate Iron & Steel Co., East Chicago, Ind., *for mail,* care company, member to March 1922.

NEWBOLD, L. T. (Jr.-3), Junior Aid, 1853 St. N. W., Washington, D. C.

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NIGH, J. D., The Western Foundry Co., *for mail,* 4249 Drexel Blvd., Chicago, Ill., member, to April 1922.

NOYES, L. C., Engineering Dept., Union Drop Forge Co., 1746 N. Kostner Ave., Chicago, Ill., *for mail*, care company, member, to March 1922.

NUGENT, John (M-3), Asst. Fore. Heat Treat. Dept., 604 E. South St., South Bend, Ind.

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RAFFEL, W. F., Owner, W. F. Raffel Co., Diemakers, *for mail*, 2319 N. Kenneth Ave., Chicago, Ill., member, to October 1922.

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ROSS, David N. (M-3), Pres., 21 W. South St., Indianapolis, Ind.

ROWE, Harry E. (A-3), Sales., Midvale Steel & Ordnance Co., Widener Bldg., Philadelphia, Pa.

ROWSEY, T. A., Division Supt., Goodman Mfg. Co., *for mail*, 8529 S. Morgan St., Chicago, Ill., member, to April 1922.

ROYEK, M. J., Miehle P. P. & Mfg. Co., Chicago, *for mail*, 1515 W. Monroe St., Chicago, Ill., member, to March 1922.

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SHAW, Wm. C. (M-3), Pyrometer Mgr., 1010 Quimby St., South Bend, Ind.

SHEPARD, C. C. Jr., Foreman Straightening Dept., Ingalls Shep. Div., Wyman Gordon Co., Harvey, Illinois. *for mail*, care company, member, to March 1922.

SHERMER, N. H. (M-4), Met., 96 St. James St., St. Catharines Ont., Detroit, Mich

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SINCLAIR, C. E. (A-3), Sales., The Betz-Pierce Co., Cleveland, Ohio.

SLAUGHTER, Roy (A-3), Sales., Crucible Steel Co., 437 S. Illinois St., Indianapolis,

SMART, C. F., Metallurgist, Wyman Gordon Co., Harvey, Illinois, *for mail*, care company, member, to March 1922.

SMITH, R. Robert (M-4), Met., Robert H. Hassler, Ind., 1535 Naomi St., Indianapolis, Ind.

SKAROUPKA, Thomas (M-3), Heat Treater, 3626 E. 104th St., Cleveland, Ohio.

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TALLEY, Wallace J. (M-3), Asst. Chem., 1926 New Hampshire Ave., N. W., Washington, D. C.

THOMAS, C. W. (M-4), 508 North Hiland Ave., Pittsburgh, Pa.

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VANNICK, J. S. (M-3), Research Oper., 2034 "F" Street, N. W., Washington, D. C.

VIGEANT, Oscar (M-4), Hemphill Mfg. Co., Clay St., Pawtucket, R. 1.

VOIGT, J. S. (M-4), Plant No. 3, Timken Detroit, Axle, Detroit, Mich. Ind.

WAARICH, O. W., Hardener, Pheoll Mfg. Co., Chicago, Ill., *for mail,* 3758 Palmer St., member, to March 1922.

WAGSTAFFE, T., Chief Inspector, Goodman Mfg. Co., *for mail,* 6623 S. Winchester Ave., Chicago, Ill., member, to April 1922.

WALROTH MFG. CO. (S-4), First & O Sts., Boston, Mass.

WATTS, A. W., Asst. Metallurgist, A. Finkl & Sons, *for mail,* 2257 Argyle Street, Chicago, Ill., member, to April 1922.

WHEELER, F. G., Mech. Eng., Miehle P. P. & Mfg. Co., Chicago, *for mail,* care company, 1953 Hastings St., Chicago, Ill., member, to March 1922.

WILKINS, Chas., Heat Treater, Doehler Die Castings Co., *for mail,* 6436 Blackstone Ave., Chicago, Ill., member, to March 1922.

WILLIS, Rose E. (A-4), 1401 David Whitney Bldg., Detroit, Mich.

WILSON, Robt. W. (M-4), Vulcan Motor Axle Co., Detroit, Mich.

WOLF, Paul, Asst. Foreman, Heat Treating Dept., Ingalls Shep. Div., Wyman Gordon Co., Harvey, Illinois, *for mail,* 21 Broadway, Blue Island, Illinois, member, to March 1922.

WOLFE, H. S. (M-3), 726 Pembroke Road, Bethlehem, Pa.

WOOD, Harold F., Chief Metallurgist, Ingalls Shepard Division, Wyman Gordon Co., Harvey, Illinois, *for mail,* 6745 Ridgeland Ave., Chicago, Ill., member, to March 1922.

WOODS, Noble (M-4), Fur. Mgr., Indianapolis Tool & Mfg. Co., 205 W. South St., Indianapolis, Ind.

ZENKERE, K. D., Salesman, Vanadium Alloys Steel Co., Chicago, Ill., *for mail,* 5555 Blackstone Ave., Chicago, associate, to March 1922.

CHANGES OF ADDRESS

ARTHUR, Walter (Member) Chemist & Met., Haynes Auto Co., Kokomo, Ind., changed to 600 W. Walnut Street, Kokomo, Ind.

BANKS, R. C. (Member) Asst. Met., Maxwell Motor Car Co., Detroit, Mich., and *for mail,* 521 Rhons Ave., Detroit, Mich., changed to 5113 Rhons Ave., Detroit, Michigan.

BARKER, T. E. (Member) Production Mgr., Miehle Printing Press & Mfg. Co., 14th and Robey Sts., Chicago, Ill., and *for mail,* 2435 N. Albany Ave., Chicago, Ill., changed to Denver Rock Drill & Mfg. Co., Denver, Colorado.

BEEARS, Byron (Member) 401 N. Street, Reading, Pa., changed to 401 North 10th St., Reading, Pa.

BOOTH, Wilfred E. (Associate) 173 Farmington Ave., Waterbury, Conn., changed to The Foxboro Co., Foxboro, Mass.

BOURG, Joseph N. (Associate) Secy., Park Chemical Co., 29 Lovett St., Detroit, Michigan, changed to 3467 Lovett Street, Detroit, Michigan, and *for mail,* 296 Lawrence Ave., Detroit Michigan.

BURLEIGH, R. W. (Member) Metallurgist, U. S. Ball Bearing Co., Palmer & Kolmar Ave., Chicago, Illinois, changed to 5419 W. Cortez St., Chicago, Illinois.

CHILES, George S. (Member) Mechanical Engineer, American Steel Foundries, 332 South Michigan Ave., Chicago, Ill., changed to 4304 Lake Park Ave., Chicago, Ill.

CLARK, Reginald (Member) Asst. Supt., G. H. Williams & Co., Buffalo, N. Y., and *for mail,* 221 N. Park Ave., Buffalo, N. Y., changed to 175 Norwalk Ave., Buffalo, N. Y.

COLES, George T. (Member) Foreman, Heat Treat. Dept., H. Mueller Mfg. Co., Decatur, Illinois, and *for mail,* 1230 N. Edward St., Decatur, Illinois, changed to 1536 N. Main Street, Decatur, Illinois.

COPELAND, C. W. (Member) Metallurgist, Timken Roller Bearing Co., Detroit, Michigan, changed to Timken-Detroit Axle Co., Waterloo Ave., Plant No. 3, Detroit, Michigan.

DAWE, C. N. (Member) Met. Engr., Studebaker of Corp., Detroit, Michigan, and *for mail,* 730 Longellow Ave., Detroit, Michigan, changed to 2426 Longellow Ave., Detroit, Michigan.

DEVINE, Harry A. (Member) 225 N. Court Street, Rockford, Illinois, changed to 2011 W. Adams Street, Chicago, Illinois.

DOBLE, W. A. (Member) *for mail,* 637 Call Bldg., San Francisco, Calif., changed to 714 Harrison Street, San Francisco, Calif.

EDINGER, John J. (Member) Tool Hardener, Brown Lipe Chapin Co., Syracuse, N. Y., and *for mail,* 131 Oakwood Ave., Syracuse, N. Y., changed to 435 Burnet Ave., Syracuse, N. Y.

EVES, A. P. (Member) Chemist, International Harvester Co., 6224 Eberhart Ave., charged to 3445 Irvine Ave., Berwyn, Illinois.

FAIRFIELD, J. A. (Associate) Secy. Modern Equipment Co., Taunton, Mass., changed to P. O. Box 415, Foxboro, Mass.

FITZGERALD, J. J. (Member) Asst. Metallurgist, Maxwell Motor Co., Detroit, Michigan, and *for mail,* 254 Connecticut Ave., Detroit, Michigan, changed to 231 California Ave., Detroit, Michigan.

GAROVE, Arthur S. (Member) Forge Foreman, American Forge & Machine Co., Detroit, Michigan, and *for mail* 344 Newport Ave., Detroit, Michigan, changed to 402 Chandler Ave., Johnstown, Pa.

HAGGERTY, A. T. (Member) Metallurgist, General Motors Laboratory, 1623 E. Grand Boulevard, Detroit, Michigan, changed to Central Gear Co., Detroit, Michigan.

HEATH, W. E. (Member) Foreman, International Harvester Co., 10902 Vernon Ave., Chicago, Ill., changed to 11315 Perry Ave., Pullman Station, Chicago, Illinois.

HENNINGER, Russel B. (Member) Foreman, Detroit, Gear & Machine Co., 1361 Berwick Ave., Detroit, Michigan, changed to 5449 Berwick Ave., Detroit, Michigan.

HOVEN, J. R. (Member) Ch. Chemist, 3200 29th Ave., S. Minneapolis, Minn, changed to 823 Washington Ave., S. E. Minneapolis, Minn.

JONES, John D. (Associate) United Steel Co., 912 Ford Bldg., Detroit, Michigan, changed to 518 Ford Building, Detroit, Michigan.

KELLEY, J. W. (Associate) 803 W. Superior Ave., Cleveland, Ohio, changed to 1111 W. Superior Ave., Cleveland, Ohio.

KIMBERLY, Silas A. (Member) Chemist, 2518 Midland Ave., Syracuse, N. Y., changed to 10 Swift Street, Auburn, N. Y.

LINDQUIST, Birger W. (Member) Supt., Vixson Mfg. Co., 1098 St. Clair Ave., Detroit, Michigan, changed to 4780 St. Clair Ave., Detroit, Michigan.

MADSEN, P. C. (Member) 4515 9th Street, Rock Island, Illinois, changed to Granda, Minnesota.

MAIN, Walter C. (Member) Metallurgist, Carnegie Steel Co., Farrell, Pa., changed to 10600 Euclid Ave., Cleveland, Ohio.

MILLER, Joseph (Member) 215 Begole Street, Detroit, Michigan, changed to 6399 Begole Street, Detroit, Michigan.

MULL, E. K. (Member) 114 N. Second St., Jeannette, Pa., changed to 107 W. Seventh St., Plainfield, N. J.

PERRY, Clyde R. (Member) Consulting Metallurgist, 30 Church Street, New York City, changed to 349 Wethersfield Ave., Hartford, Conn.

PETERSON, Walter C. (Member) Supervisor of Materials, Packard Motor Car Co., Detroit, Michigan, changed to 5174 Parker Ave., Detroit, Michigan.

PFEIFER, Carl B. (Associate) Salesman, *for mail,* 1723 Lafayette Blvd., Detroit, Michigan, changed to 1594 Pennsylvania Ave., Apt. No. 14, Berwick, Detroit, Michigan.

PURDON, Henry (Member) *for mail,* 632 Dickinson Street, Springfield, Mass., changed to 100 Westmoreland Ave., Longmeadow, Mass.

ROBERTS, Edw. E. (Member) Supt., New England Metallurgical Corp., 9 Alger St., Boston, Mass., and *for mail,* 131 Magazine Street, Cambridge, Mass., changed to 9 Alger Street, South Boston, Mass.

ROSE, C. B. (Member) Moline Plow Co., Moline, Ill., changed to 785 20th Ave., East Moline, Illinois.

ROTH, Ed. B. (Member) Pres. & Mgr., Simplex Sterling Gear Co., 751 Euclid Ave., St. Louis, Mo., changed to 5163 Gates Ave., St. Louis, Mo.

SHELDON, A. J. (Member) Engineer, American Rolling Mill Co., Middletown, Ohio, changed to 707 Yankee Road, Middletown, Ohio.

SKOOG, Carl F. (Member) Foreman, Studebaker Corp., Plant No. 2, South Bend, Ind., and *for mail,* 317 E. Broadway, South Bend, Ind., changed to 711 E. Harvey Street, South Bend, Ind.

SOWDER, Stanley (Member) Metallurgist, American Twist Drill Co., 70 Davenport Street, Detroit, Michigan, changed to 100 Davenport Street, Detroit, Michigan.

STANTON, R. F. V. (Member) Engr., *for mail,* 282 Laurel Street, Hartford, Conn changed to 33 Hamilton Street, Hartford, Conn.

SWANBERG, Gus (Member) Supt. L. P. Halliday Co., Streator, Ill., and *for mail,* 116 10th Street, Streator, Ill., changed to Gen'l. Dely., Decatur, Illinois.

TREADWAY, Alfred A. (Member) 146 Glynn Ct., Detroit, Michigan, changed to 710 Glynn Ct., Detroit, Michigan.

WILKINSON, H. P. (Member) Chemist, DeVibbie's Mfg. Co., Toledo, Ohio, and *for mail,* 1117 Horace, Toledo, Ohio, changed to 232, 21st Street, Toledo, Ohio.

WILLIAMS, Dean R. (Associate) Pardner. Williams & Holff Co., 460 Webster Place, Milwaukee, Wis., changed to 262 Palace Theatre Bldg., Milwaukee, Wis.

WILLIAMS, R. H. (Member) Supt., Arkell & Douglas, Inc., 44 Whitehall St., New York City, changed to Sidney Williams & Co., Constitution Rd., Dulwich Hill, Australia.

WILLIAMS, R. L. (Associate) Dist. Mgr., Crucible Steel Co. of America, 475 W. Lafayette Blvd., Detroit, Michigan, changed to 1723 Lafayette Blvd., Detroit, Michigan.

ZONKER, L. W. (Member) Metallurgist, Mitchell Motor Car Co., 1436 Quincy Ave., Racine, Wisconsin, changed to 822 Belmont Ave., Racine, Wisconsin.

MAIL RETURNED

BROWN, N. E., Box 155, Los Angeles, Cal.
CLARK, G. W., 165 Main St., W. Springfield, Mass.
VERICH, A. L., Davenport Locomotive Works, Davenport, Iowa.
WICKSTROM, John, 3042 Snelling Ave., Minneapolis, Minn.

Commercial Items of Interest

D. K. Bullens, well known author of "Steel and Its Heat Treatment," has organized a company located in Philadelphia, to do heat treating work and also to act as consulting engineers, making investigations and reports in addition to commercial heat treating.

The plant and offices are located at 909-911 W. Tioga street. Mr. Bullens is president and treasurer of the firm, and associated with him are W. S. Murphy, as vice president, and F. D. Metz, as secretary.

One of the novel features established by this progressive firm is the introduction of a co-operative service whereby for a small monthly retainer the firm holds itself in readiness to offer advice and to act in a consulting capacity for any firm needing such service.

Walter F. Graham has resigned as metallurgist with the Spicer Manufacturing Co., Plainfield, N. J., and is now associated with the Henry Souther Engineering Co., consulting, metallurgical and inspecting engineers, Hartford, Conn. Mr. Graham was formerly associated with the late Henry Souther as metallurgist for the Standard Roller Bearing Co., and subsequently with the Ferro Foundry & Machine Co., and the Ingersoll-Rand Co., which experience is particularly fitting for the service rendered by the metallurgical department of the Henry Souther Engineering Co.

Announcement has been made of the organization of the Engineers' Club of the Lehigh Valley during the early part of February. The club issued its first 4-page bulletin on March 15 giving the details of organization. The officers elected are as follows: R. P. Hutchinson, president Bethlehem Fabricators, Bethlehem, Pa., president; J. Madison Porter, consulting engineer, Easton, Pa., and J. S. Wise Jr., Pennsylvania Power & Power Co., Allentown, Pa., vice presidents; and T. E. Butterfield, Lehigh University, Bethlehem, Pa., secretary-treasurer. J. E. Halking, Ingersoll-Rand Co., Phillipsburg, N. J., and chairman, Lehigh Valley Chapter, American Society for Steel Treating, was elected a member of the board of managers.

The Electric Furnace Construction Co., Philadelphia, announces it has secured an order from the Sociedad Espanola De Construccion Naval, Madrid, Spain, for a new design of electrically-heated car-type annealing furnace for heat treatment of large steel ingots and forgings. The furnace will be the largest electric furnace in the world for this particular class of work, and the dimensions are 6800 millimeters long x 4750 millimeters wide x 4140 millimeters high, and will

TRANSACTIONS
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Vol. 1 Cleveland, June, 1921 No. 9

EXTENDING THE USE OF ALLOY STEELS

With the invention of the automobile and its continually growing importance in the industrial activity of the United States, the production of alloy steels has increased from a very low figure in 1908 to something over 2,000,000 tons in 1920. To be sure the automobile industry has not produced the only demand for alloy steel, but because of its rapid and uninterrupted growth, it has represented a goodly volume of the business. Peculiar requirements of the motor car, including ruggedness, resistance to shock, long serviceability and minimum weight, were responsible for the development and adaptation of this grade of steel for automotive parts. While straight carbon steel in various grades could be made to stand practically all of the physical requirements, the mass required to produce these qualities was so great that the assembled weight was excessive. Alloy steel offered similar physical properties but with considerable reduction in weight.

As illustrative of the rise of alloy steel, an article appearing elsewhere in this issue reviews the production of bessemer, open-hearth, crucible and electric steels for the last 54 years. A chart appearing with the article shows that within the 12 years the output of steel made by the last three methods has witnessed remarkable increase while bessemer production has remained at about the same level. Explanation of this lies in the fact that of the four processes of making steel, the bessemer alone does not adapt itself to the manufacture of alloy steel. Another chart with the same article shows the tremendous growth of the electric furnace method between 1908 and 1918. Open-hearth manufacture stands second in rate of growth, this process lending itself very readily to alloy steel production because of the simplicity of refining the metal in quantity.

Alloy steels are made containing different elements and different combinations of elements, each type having been so well standardized that it satisfies some definite requirement. Each type necessitates a definite heat treatment and to this fact, perhaps more than any other, is attributed the recent growth of the heat treating profession, for without careful and precise treatment the best of steel may be made worthless. The subject is too broad and too complex to discuss in detail but it may be said without reservation that alloy steel has come to stay and its application still is in its infancy. So far, its use is restricted largely to the automotive and high speed tool fields. However, its success there, coupled with a lower cost on a quality basis gives assurance that application will spread to other fields. It has been predicted and safely too that the time will come when alloy structural and fabricating steel will be used in considerable quantities for

buildings and bridges, for rails, locomotives, passenger and freight car parts, in boilers, wire rope construction and numerous other types of fabrication. This expansion predicts a greater field for steel treating.

PROFESSOR E. D. CAMPBELL ELECTED TO HONORARY MEMBERSHIP

At a meeting of the Board of Directors, on April 9, a petition was received from a large number of former students of Prof. E. D. Camp-

PROF. E. D. CAMPBELL

bell nominating him for honorary membership in the American Society for Steel Treating. The Board of Directors unanimously granted this petition in recognition of Professor Campbell's research work carried on in the laboratories of the University of Michigan, Ann Arbor, Mich., for the past 30 years.

Professor Campbell is director of the chemical laboratories at the university and his research work has dealt with the correlation of the chemical constituents to the physical properties of steel, considering mainly the theoretical aspect of the subject rather than the practical application of the ideas developed by the investigations.

Lt. Col. A. E. White, national president of the Society, presented Professor Campbell with his certificate of honorary membership at the meeting of the Detroit chapter held on May 21.

REPORT OF NOMINATING COMMITTEE, MAY 10, 1921

To the Secretary of the American Society for Steel Treating:

The National Nominating Committee, meeting according to the Constitution of the American Society for Steel Treating, selected as unanimous choice of those present the following men for nominees for office for the coming year.

President—F. P. Gilligan, Hartford, Conn.
1st Vice President—F. C. Lau, Chicago, Ill.
2nd Vice President—R. J. Allen, Springfield, Mass.
Treasurer—J. V. Emmons, Cleveland, Ohio.
Director—J. J. Crowe, Philadelphia, Pa.

According to Section 10 of Article VII of the By-Laws we are enclosing the written consent of these gentlemen to act.

Yours sincerely,
NATIONAL NOMINATING COMMITTEE,
American Society for Steel Treating.
(Signed) A. W. F. GREEN.
A. E. BELLIS.
C. U. SCOTT.
J. FLETCHER HARPER, Chairman.

REDUCED RATES TO INDIANAPOLIS

We are very glad to announce that the railroads of the country, through the Central Passenger Association, have granted fare and a half round trip for members of the Society and their dependents, for the Indianapolis Convention and Exhibition, Sept. 19 to 24. A large number of members and guests are always in attendance at this Convention, thus the railroads unanimously decided to recognize the Society to the extent of granting the fare and a half for the round trip.

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification certificate must be presented to the ticket agent for the purchase of the round trip ticket. This identification certificate will be mailed to all the members of the Society before the first of September.

The reduction of railroad fares will contribute materially to an increase in attendance and there is no doubt but that the number visiting Indianapolis will be in excess of the 10,000 in attendance at Philadelphia.

HOTELS IN INDIANAPOLIS

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reser-

FRANK P. GILLIGAN
Nominee for National President of the Society

F. C. LAU
Nominee for First Vice President of the Society

R. J. ALLEN
Nominee for Second Vice President of the Society

J. V. EMMONS
Nominee for National Treasurer of the Society

J. J. CROWE
Nominee for National Director of the Society

vations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then take the letter with you to present to the hotel clerk at Indianapolis when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$6.00 " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$5.00 to $8.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 Rooms	Not over $3.50 per day
Haugh Hotel	60 "	" " " " "
Linden Hotel	250 "	" " " " "
Majestic Hotel	59 "	" " " " "
Roosevelt Hotel	187 "	" " " " "
Royal Hotel	85 "	" " " " "

EXHIBITORS AT INDIANAPOLIS CONVENTION

The list of 40 firms given below have already contracted for space, and there are a number of other uncompleted contracts in the National office.

With the Convention still three months off, it is easily seen that this Exhibition is going to be one of the best ever held. The reason for the wonderful advance sale of space has been due primarily to the fact that the manufacturers realize this is a year in which they should stimulate trade, and also that it is a year in which their products will be sold upon their merits; and consequently they are anxious to present their products to the 10,000 visitors who will be in attendance at the Convention.

The advance sale is far in excess of the sale of space for the Philadelphia show last year.

A list of exhibitors who have contracted for space follows:

	Space No.
Charles Englehard, pyrometers and temperature control	4
George J. Hagen Co., electric and gas fired furnaces	8-9
Taylor Instrument Co., recording instruments	28
Brown Instrument Co., recording instruments	17
Quigley Furnace Specialties Co.	32

Hoskins Mfg. Co., electric furnaces and pyrometers 33
Eaton Electric Co., electric furnaces 20
Leeds & Northrup Co., electric furnaces and pyrometers.....23-36
Bausch & Lomb Optical Co., metallographic equipment 24
William Ganschow Co., gears 37
Armstrong Cork & Insulation Co. 27
Spencer Turbine Co., air compressors..... 45
The Iron Trade Review, publications 58
Driver Harris Co., alloy pots and boxes 49
Crucible Steel Co. of America, steel 50-51-63
Halcomb Steel Co., steel 69-82
Bell & Gossett Co, case hardening materials 74
Case Hardening Service Co., carburizing materials 87
The Iron Age, publications 75
General Alloys Co., "Q" Alloys 94-107
Colonial Steel Co., steel 108
Electric Alloy Steel Corp., steel 100
E. C. Atkins Mfg. Co., saws and cutting off machines..... 154-153
Herman A. Holz, metallographic equipment .....Unassigned
Bureau of Standards research work 123-124
Deeds & Chapin, Cinch Cement 81
Bethlehem Steel Co., steel 44-57
Marschke Mfg. Co., grinders and buffers 31
Indianapolis Drop Forging Co., forgings 19
Simonds Mfg. Co., steel and steel products 34
Heppenstall Forge & Knife Co., forgings, die blocks 126
Tate-Jones Inc., furnaces 25
Witherow Steel Co., steel 62
Midvale Steel Co., steel 18
Selas Co. 3
Smith Gas Engineering Co., gas producers 7
Vanadium Alloys Steel Co., steels 125
General Electric Co., electrical equipment 35
Westinghouse Electric Mfg. Co., electrical equipment .....A & B
Ludlum Steel Co., steel 30-43
Bristol Co., pyrometers 40

LETTERS TO THE EDITOR

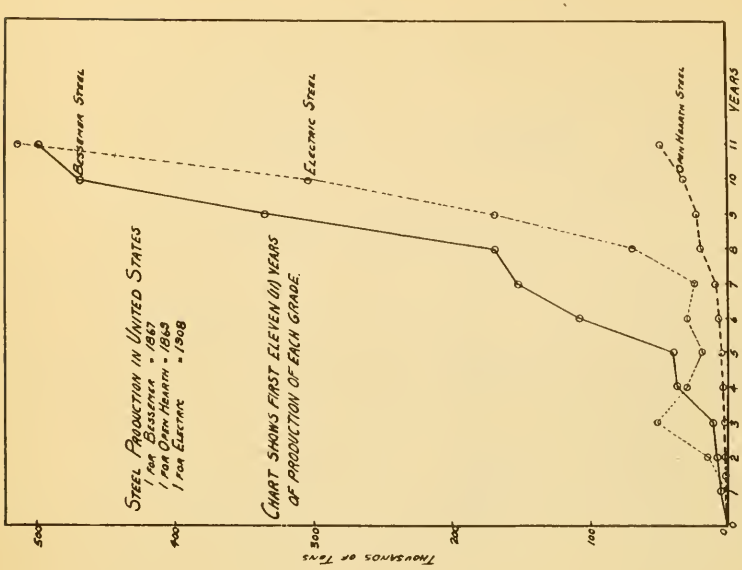
May 19, 1921.

Editor Transactions:

I believe I have an appreciable, though not overwhelming sense of modesty, and it received a rude jolt when I read the last paragraph of the story of the Philadelphia Membership Campaign, appearing in the May TRANSACTIONS, and of which I was credited with being the author. Please let me say that I did not write this paragraph and that it was added without my knowledge, apparently by some kind friend. I certainly do not wish to claim, and will not accept, any special credit for the success of the campaign. We all worked together. I believe that all results were largely in proportion to enthusiasm for the cause.

(Signed) H. C. Knerr
Philadelphia Chapter

The above portion of a letter is self-explanatory. The statement to which Mr. Knerr objects was not written by Mr. Knerr and through fault of the editor was allowed to appear improperly under his signature.



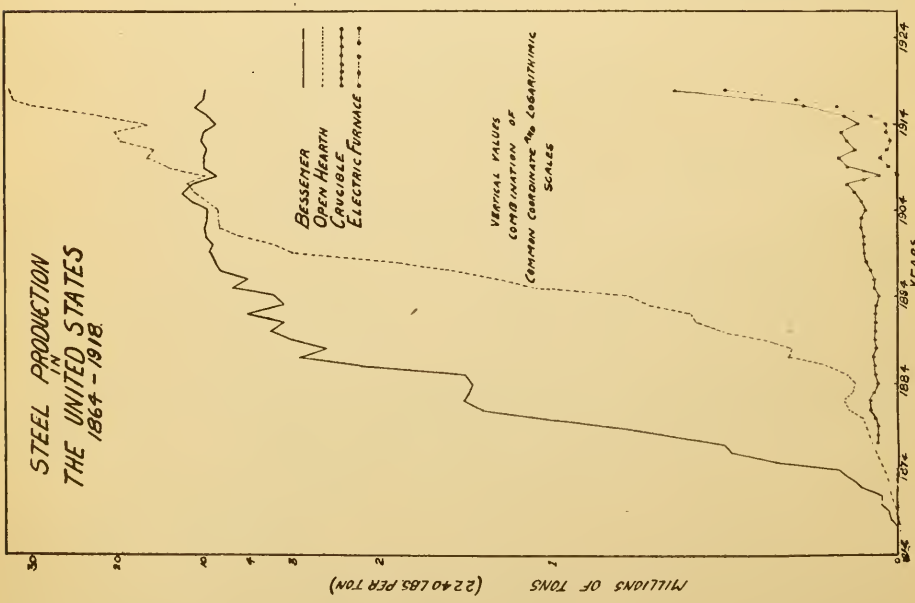


Fig. 1—Steel Production in the United States, 1864-1918. Fig. 2—First 11 Years of Production of Various Grades of Steel

ALLOY STEEL—ITS RISE AND SECRETS

By Lieut. Col. A. E. White*

(A Paper Presented Before Several Eastern Chapters)

Turning to the Encyclopaedia Britannica we find the following: "Iron, the most abundant and the cheapest of the heavy metals, the strongest and most magnetic of known substances, is perhaps also the most indispensable of all save the air we breathe and the water we drink. For one kind of meat we could substitute another; wool could be replaced by cotton, silk or fur; were our common silicate glass gone, we could probably perfect and cheapen some other of the transparent solids; but even if the earth could be made to yield any substitute for the forty or fifty million tons of iron which we use each year for rails, wire, machinery, and structural purposes of many kinds, we could not replace either the steel of our cutting tools or the iron of our magnets, the basis of all commercial electricity. This usefulness iron owes in part, indeed, to its abundance, through which it has led us in the last few thousands of years to adapt our ways to its; but still in chief part first to the single qualities in which it excels, such as its strength, its magnetism, and the property which it alone has of being made at will extremely hard by sudden cooling and soft and extremely pliable by slow cooling; second, to the special combinations of useful properties in which it excels, such as its strength with its ready welding and shaping both hot and cold; and third, to the great variety of its properties. It is a very Proteus. It is extremely hard in

*Director, department of engineering research, University of Michigan, Ann Arbor, Mich., and national president American Society for Steel Treating.

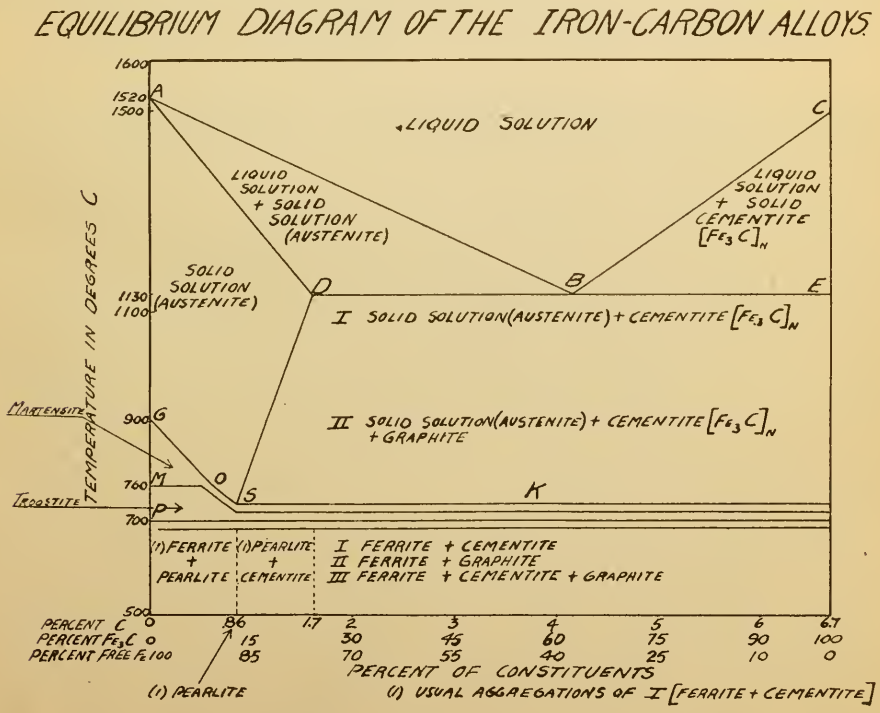


Fig. 3—Equilibrium Diagram of the Iron-Carbon Alloys

Table I

MENDELEEFF'S PERIODIC TABLE

Series	Group O	Group I RH R_2O	Group II RH_2 RO	Group III RH_3 R_2O_3	Group IV RH_4 RO_2
1	....	H = 1.008	....	....	....
2	He = 3.99	Li = 6.94	*Gl = 9.1	B = 11.0	C = 12.0
3	Ne = 20.2	Na = 23.0	Mg = 24.32	Al = 27.1	Si = 28.3
4	A = 39.88	K = 39.1	Ca = 40.07	Sc = 44.1	Ti = 48.1
5	....	Cu = 63.57	Zn = 65.37	Ga = 69.9	Ge = 72.5
6	Kr = 82.92	Rb = 85.45	Sr = 87.63	Yt = 89.0	Zr = 90.6
7	....	Ag = 107.88	Cd = 112.40	In = 114.8	Sn = 119.0
8	X = 130.2	Cs = 132.81	Ba = 137.37	La = 139.0	Ce = 140.25
9	....	....	....	Er = 167.7	....
10	....	....	....	....	....
11	....	Au = 197.2	Hg = 200.6	Tl = 204.0	Pb = 207.1
12	....	....	Ra = 226.4	....	Th = 232.4

Elements not placed in above table are Tb = 159.2, Dy = 162.5, Tm = 168.5, Lu = 174.0, Nt = 222.4 = Niton = Emanium = radium emanation

our files and razors, and extremely soft in our horse-shoe nails, which in some countries the smith rejects unless he can bend them on his forehead; with iron we cut and shape iron. It is extremely magnetic and almost nonmagnetic; as brittle as glass and almost as pliable and ductile as copper; extremely springy, and springless and dead; wonderfully strong, and very weak; conducting heat and electricity easily, and again offering great resistance to their passage; here welding readily, there incapable of welding; here very infusible, there melting with relative ease. The coincidence that so indispensable a thing should also be so abundant, that an iron-needing man should be set on an iron-cored globe, certainly suggests design. The indispensableness of such abundant things as air, water and light is readily explained by saying that their very abundance has evolved a creature dependent on them. But the indispensable qualities of iron did not shape man's evolution, because its great usefulness did not arise until historic times, or even, as in case of magnetism, until modern times.

"These variations in the properties of iron are brought about in part by corresponding variations in mechanical and thermal treatment, by which it is influenced profoundly, and in part by variations in the proportions of certain foreign elements which it contains; for, unlike most of the other metals, it is never used in the pure state. Indeed pure iron is a rare curiosity. Foremost among these elements is carbon, which iron inevitably absorbs from the fuel used in extracting it from its ores. So strong is the effect of carbon that the use to which the metal is put, and

Table I

MENDELEEFF'S PERIODIC TABLE

Series	Group V RH_3 R_2O_5	Group VI RH_2 RO_3	Group VII RH R_2O_7	Group VIII RO_4		
1	....	....	....	....		
2	N = 14.01	O = 16.0	F = 19.0	....		
3	P = 31.04	S = 32.07	Cl = 35.46	....		
4	V = 51.0	Cr = 52.0	Mn = 54.93	Fe = 55.84	Ni = 58.68	Co = 58.97
5	As = 74.96	Se = 79.2	Br = 79.92	....		
6	*Nb = 93.5	Mo = 96.0	....	Ru = 101.7	Rh = 102.9	Pd = 106.7
7	Sb = 120.2	Te = 127.5	I = 126.92	....		
8	Pr = 140.6	Nd = 144.3	....	Sa = 150.4	Eu = 152.0	Gd = 157.3
9	Yb = 172.0	....	....	....		
10	Ta = 181.5	W = 184.0	....	Os = 190.9	Ir = 193.1	Pt = 195.2
11	Bi = 208.0	....	....	....		
12	....	U = 238.5	....	....		

*Gl = Glucinum = Be = Beryllium
Nb = Niobium = Cb = Columbium

indeed its division into its two great classes, the malleable one, comprising steel and wrought iron, with less than 2.20 per cent of carbon, and the unmalleable one, cast iron, with more than this quantity, are based on carbon content."

Of significance in addition to the carbon are the special elements; nickel, chromium, vanadium, molybdenum, tungsten and silicon and manganese in percentages above those found in straight carbon steels.

However else we may characterize this present age we can, without any hesitancy, speak of it as the "Age of Steel." Beginning in the early sixties of the last century, at just about the time that the Civil War broke out, the first glimmerings of the present age appeared. Up to that time the only steel made was either in the cementation or crucible processes.

The increase in the production of steel in this age is indicated by the comparisons of the tonnages of steel produced in 1864 and 1918. In the former year 13,627 tons were made and in the latter year a tonnage 3260 times as great or, to be exact, 44,462,432 tons.

This growth in the consumption of steel products is shown in Fig. 1. The tonnages of bessemer, open hearth, crucible, and electric furnace steels are given from the year 1867 for bessemer, 1869 for open hearth, 1872 for crucible, and 1908 for electric furnace, to and through the year 1918. The year 1867 was selected for the bessemer, 1869 for the open hearth and 1908 for the electric furnace grades since these were the first

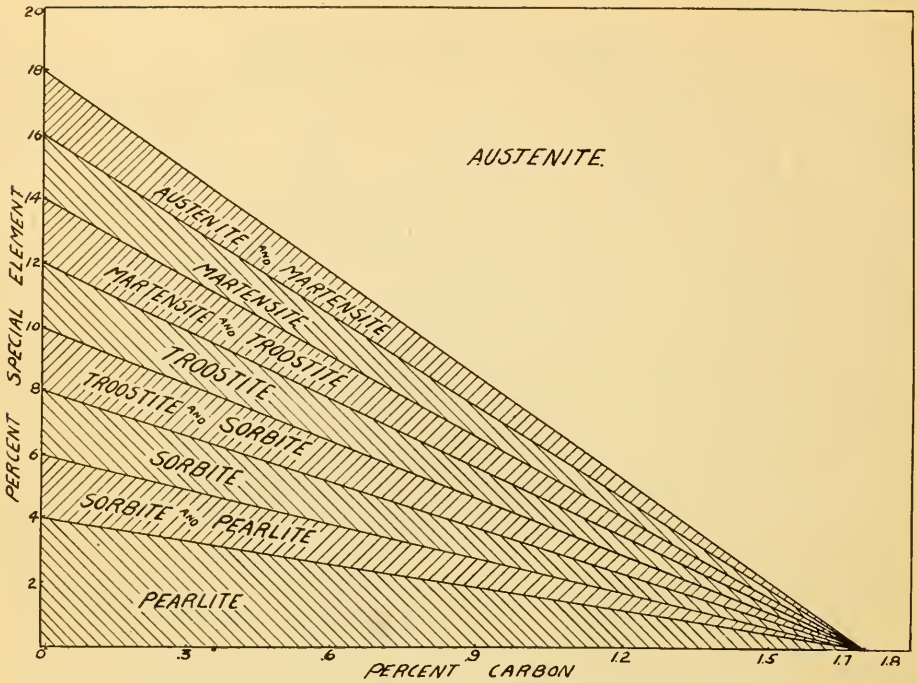


Fig. 4—General Constitutional Diagram for Special Steel in Which Special Element Tends to Hold the Carbon in Solution

years of which there is any record of the production of any appreciable tonnage of steel of these various types. The year 1872 was selected for the crucible steels since this was the first year of a separate notation for this grade. Attention is particularly called to the very rapid increase in the production of steel which has taken place in this country, and which has resulted in placing this land in a leading position in this field of activity.

For the sake of drawing attention to the remarkable rise of electric furnace steel there is shown in Fig. 2 the growth of bessemer, open hearth and electric furnace steels during their first 11 years of production. The chart demonstrates the phenomenal growth of bessemer steel, the equally phenomenal growth of electric furnace steel and the more conservative growth of open hearth steel. To be sure the production of bessemer steel is no longer on the increase owing to the acknowledged superior qualities, for most purposes, of open hearth and electric furnace steels and the impetus which improved methods of handling and other operating details have given to open hearth steels particularly, enabling them, thereby, to compete on a cost basis with bessemer steels.

It is with regret that no figures for alloy steels are given. There seems to be little data available on this point. It has been stated that there was produced during the past year about 2,000,000 tons of alloy steel. If this is the case then we would not be far from the facts if we assumed that four times the tonnage of electric furnace steel represented the tonnage of alloy steel. To be sure small quantities of alloy steel were made previous to 1908. Nickel steel has been particularly well

known for the past 25 years, although in its early days it was used almost exclusively in steel for armament purposes. Alloy steel for structural and fabricating purposes, types with which this paper is chiefly concerned only began to come into its own with the advent of the automobile. With the growth of this industry there has been a corresponding growth in the consumption of alloy steel. It is believed to be a fair prediction, though, that the day is about to break when alloy structural and fabricating steel will be used in considerable quantities in structural work, bridges and buildings, in the field of transportation for rails and for locomotives, passenger and freight car parts, in boilers, wire rope construction and numerous other types of fabrication.

The various grades of steel that will be touched upon in this article are plain carbon steels and structural and fabricating alloy steels. The term "structural and fabricating" is used as an antithesis to high speed steels for there will be no attempt to discuss at this time this latter class of steel. Of the alloy steels, discussion will center around nickel, chromium, manganese, silicon, nickel-chromium, chrome-molybdenum and chrome-vanadium.

On the part of many individuals there has been an attempt to classify these steels with a view to correlating their respective properties and enabling a prediction of properties that might be expected from other elements should they be used.

Osmond arranged a number of the elements in the order of their atomic volumes, and found by dividing their atomic weight by their specific gravity:

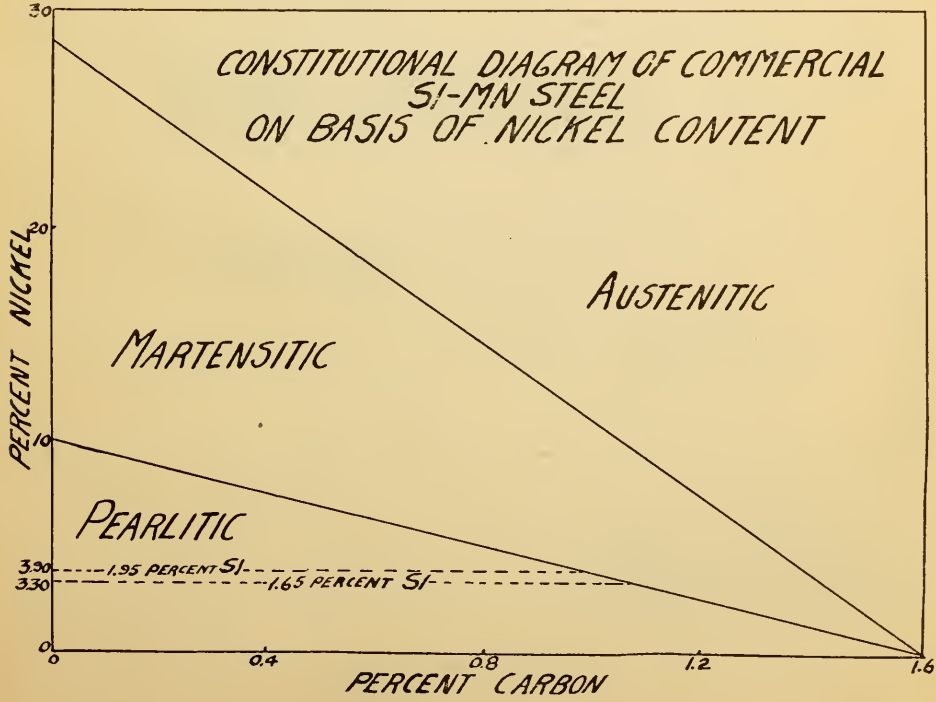


Fig. 5—Constitutional Diagram for Nickel Steels —*Sauveur*

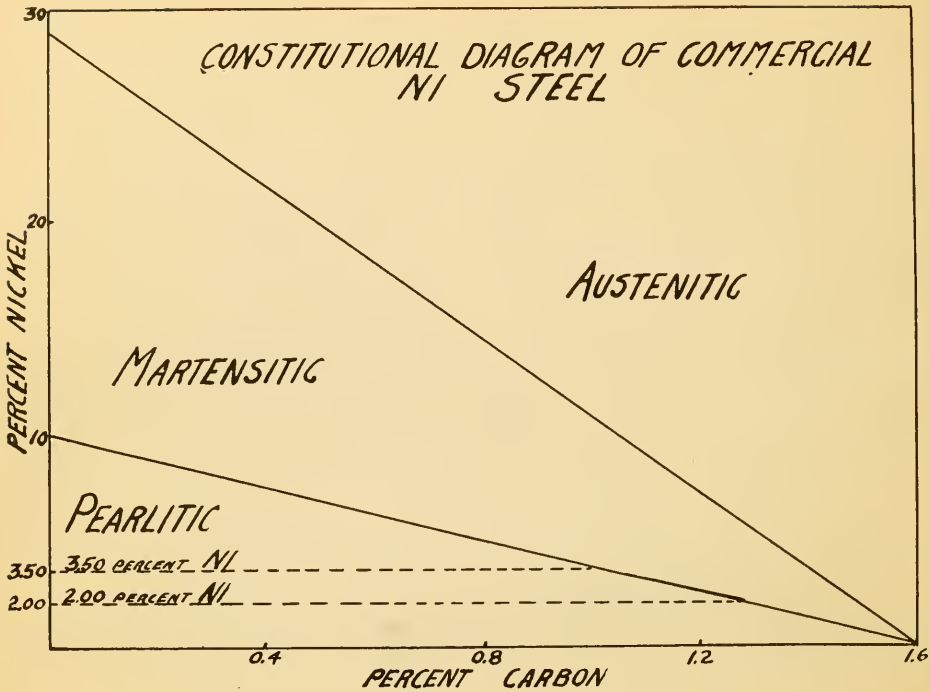


Fig. 6—Constitutional Diagram for Commercial Nickel Steels

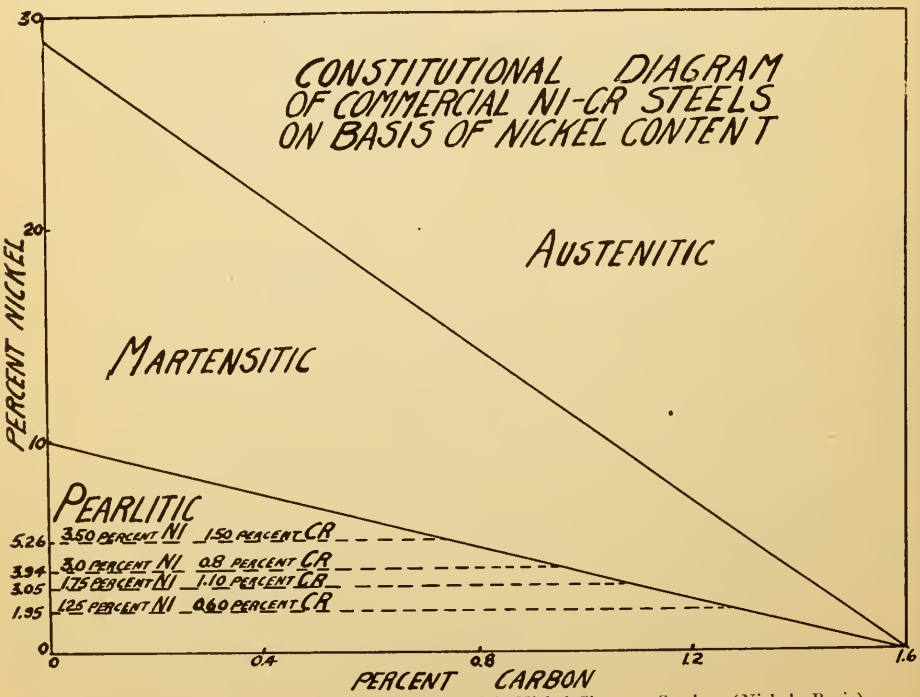


Fig. 7—Constitutional Diagram for Commercial Nickel-Chrome Steels. (Nickel Basis)

I.		II.	
Carbon	3.6	Chromium	7.7
Boron	4.1	Tungsten	9.6
Nickel	6.7	Silicon	11.2
Manganese	6.9	Arsenic	13.2
Copper	7.1	Phosphorus	13.5
		Sulphur	13.7

Elements According to Atomic Volumes.

He considered that the elements in Column I, whose atomic volumes are smaller than that of iron (7.2), delay the Ar_3, Ar_2, and Ar_1 transformations, while elements whose atomic volumes are greater than that of iron (Column II) tend to raise the temperature at which those changes occur. There can be no doubt that this arrangement is quite inadequate, because the action of the above elements cannot be arranged in two simple columns, and also because it does not take into account the fact that they may form new compounds with the carbon and the iron.

Also there have been those who have made attempts to show the relation between the position of the elements in Mendeleeff's periodic table and their effect upon the properties of iron and steel. For instance, in Group VI of Table 1 there is chromium, molybdenum and tungsten. All of these elements impart to steel certain properties which are closely analogous. It is assumed, by some, therefore, that uranium which is in the same group will impart similar properties. Within certain limits this is doubtless true. In Group IV there is silicon, titanium and zirconium. These elements have within certain limits similar deoxidizing effects on steel. Will the remaining elements in this group have similar effects? Edwards answers this question in some measure when he says:

"Nevertheless, it is more than probable that the chemical and physical action of the various elements upon iron and steel is in some way governed by their atomic or molecular constitution, and, if this be so, we may reasonably hope that some useful theory or law similar to the periodic classification of the elements will ultimately be discovered. Before this can be satisfactorily accomplished, however, the various chemical compounds which the elements are capable of forming, both with the iron and carbon, must be carefully isolated."

The open door to the secrets of alloy steel is through constitutional diagrams. The parent of all of these is the iron carbon alloy diagram given in Fig. 3. Without minutely studying this diagram we know that when steel is brought up to a temperature which, when taken in connection with its composition is the zone *ADSOG* austenite is formed, when in the zone *GOM* martensite is formed, and when in the zone *MOS* troostite is formed. Also the constituents of annealed steel in the zone below line *PS* and to the left of point *S* are ferrite and pearlite, or ferrite and sorbite, when below line *SK* but to the right of point *S* the constituents are pearlite and cementite or sorbite and cementite, and if directly at or below *S* the constituent is either pearlite or sorbite. The

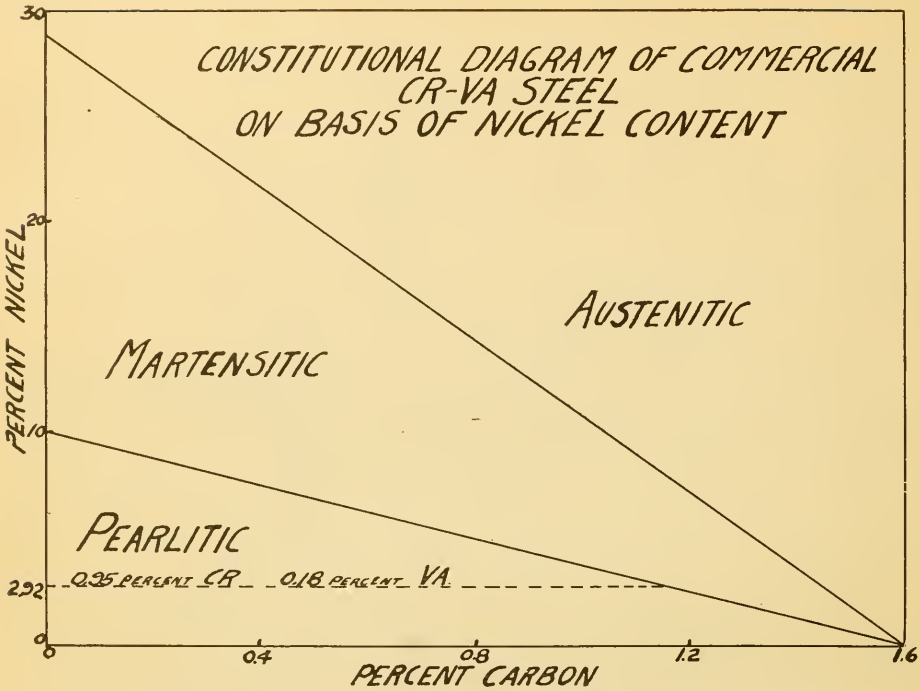


Fig. 8—Constitutional Diagram for Commercial Chrome-Vanadium Steels. (Nickel Basis)

diagram also shows by the line parallel to *OS* and the lines parallel to *PSK* that the zones just mentioned for martensite and troostite are not the only ones in which it is possible for martensite and troostite to occur. Briefly, the constitution of these constituents is as follows:

Ferrite is pure iron. All of the area given in Fig. 20, except the very blackest is ferrite. Cementite is carbide of iron containing 6.67 per cent carbon with the formula Fe_3C. It is shown in Fig. 21 as the white.

Pearlite, shown in Fig. 22, is a mechanical mixture of ferrite and cementite containing approximately 88 parts of ferrite and 12 parts of cementite with a total carbon content of 0.86 per cent. From the laminated nature of its makeup it derives its name. The black is the ferrite, the white the cementite, the two together forming the pearlite. Sorbite is essentially the same as pearlite but for the nature of the mixture of the cementite and the ferrite. These two constituents do not manifest a laminated appearance. Its appearance is given in Fig. 23. The black areas are sorbite.

Austenite is a solid solution of carbon or carbide of iron in gamma iron. Martensite and troostite are presumably transition forms between austenite on the one hand and ferrite and cementite on the other. Both martensite and troostite probably contain all three of the constituents just named—austentite, ferrite, and cementite—though in varying proportions for both the respective constituents and in each respective constituent. In Fig. 24 is shown both austenite—white—and martensite—dark and needlelike—and in Fig. 25 is both martensite—white—and troostite—dark.

This is not a good illustration of austenite and martensite. In fact

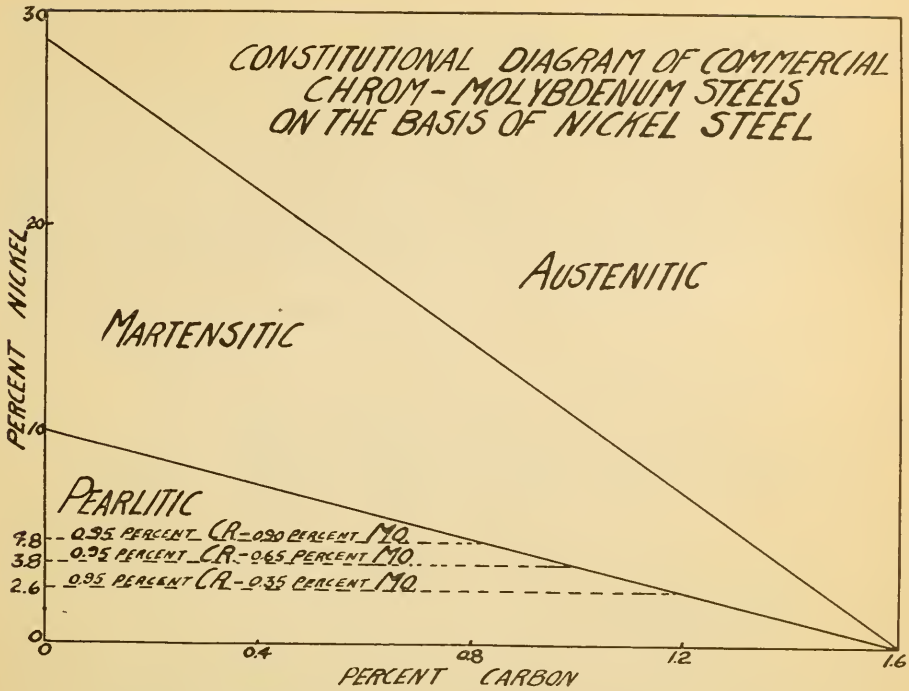


Fig. 9—Constitutional Diagram or Commercial Chrome-Molybdenum Steels. (Nickel Basis)

I doubt whether any martensite is present. The dark needles look more like slip bands or X-bands.

In alloy steels these are no more nor no less constituents than in plain carbon steels. The addition of the special element or elements rendering them special steels, however, accentuates the ease with which given desired constituents may be produced. Realizing that each of the constituents has particular properties of its own, the question of the production of special properties resolves itself into procuring given constituents of a given degree of saturation. It has been so customary to think of special steels in terms of composition and heat treatment that the desirability of at times speaking of a steel in terms of constituents has sometimes been overlooked.

Special elements probably act in one of three ways. Either they tend to keep the carbon in solution, or tend to aid in throwing it out of solution as a single or compound carbide, usually the latter, or else they tend to keep the carbide in solution within certain limits and beyond these limits aid in throwing it out of solution. Most all structural and fabricating alloy steels belong to the first class and most high speed tool steels are of the last class.

In view of the narrowing down of the subject to structural and fabricating alloy steels most of the discussion will be directed only to this class of alloy steel and but little to the other remaining classes.

A general law for the effect of special elements which tend to keep the carbide in solution is stated in three parts as follows: (a) With a constant special element content, increases in the carbon content produce tendencies for the formation of austenitic steels. (b) With a constant

carbon content increases in the special element content produce tendencies for the formation of austenitic steel. (c) The transitions from pearlite to martensite to austenite are not distinct nor sharply defined.

These laws are set forth in Fig. 4. Thus with a steel containing X per cent of special element—a per cent so low that with 0.1 per cent carbon the steel would be in the pearlite zone—the steel would be known as pearlitic; that is, on air cooling from above its critical temperature pearlite would probably be produced. With a given increase in carbon sufficient for the intersection of the content of special element and carbon to occur in the martensite zone the steel would be martensitic; that

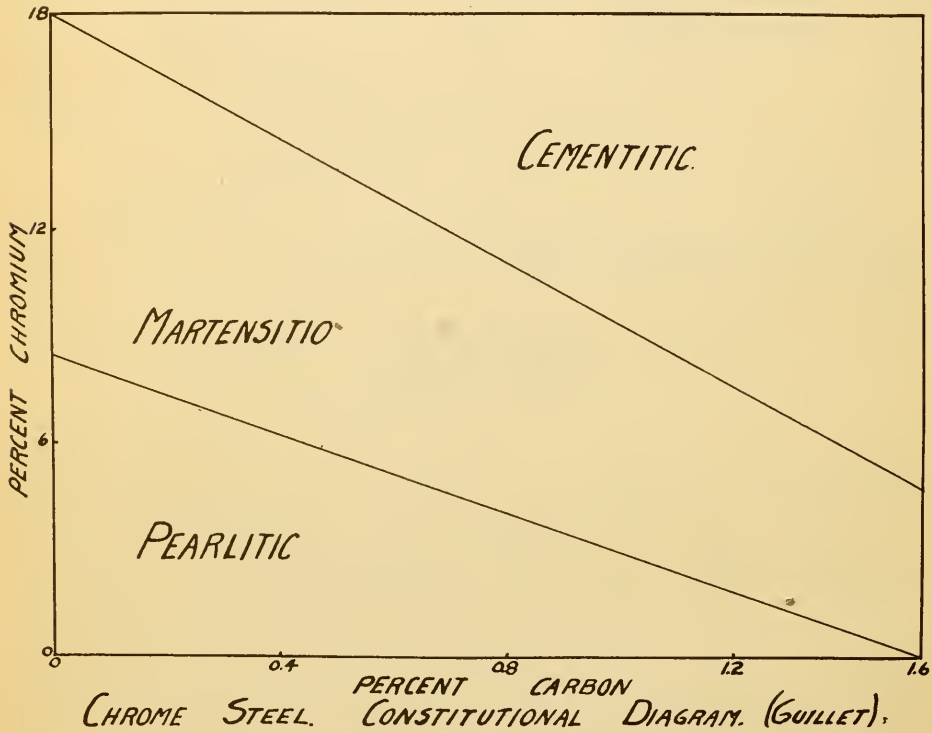


Fig. 10—Constitutional Diagram for Chrome Steels —*Sauveur*

is, on air cooling from above the critical temperature martensite would probably form. With increase in the carbon content to 1.7 per cent the steel would be austenitic; that is, on air cooling from above the critical temperature the constituent present would probably be austenite. In this same general manner it is not difficult to realize that by varying the percentages of carbon one can obtain on air cooling from above the critical temperature pearlite, transition forms between pearlite and martensite, martensite, transition forms between martensite and austenite, or austenite.

When looked at from the standpoint of a constant carbon content but a varying special element content, the same ability to get at will the constituent desired on air cooling from above the critical temperature is apparent. The only different set of conditions in this case over that last described is in the variation of the special element content in place of a

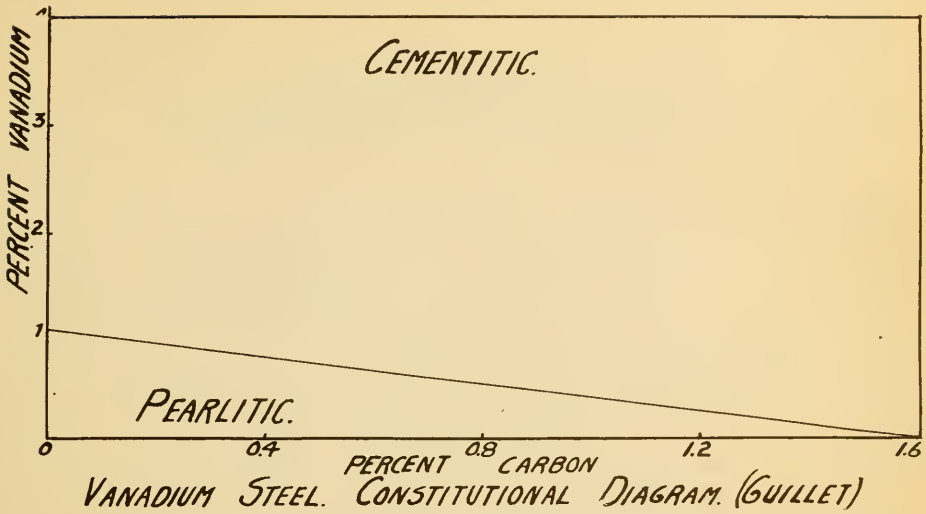


Fig. 11—Constitutional Diagram for Vanadium Steels —*Sauveur*

variation in the carbon content. It is further desired to point out that none of the constituent changes are sharp. Thus one constituent does not pass directly into another. Rather there is a gradual transition, a gradual passage.

The special elements of commercial importance are nickel, manganese, chromium, vanadium, molybdenum, tungsten and silicon. These may be added to steels individually to form ternary steels, in groups of twos to form quarternary steels, or even in groups of three, as is the case with a popular high speed steel, the special elements of which are tungsten, chromium, and vanadium, to form a quinternary steel.

Practically all of the structural and fabricating alloy steels are of

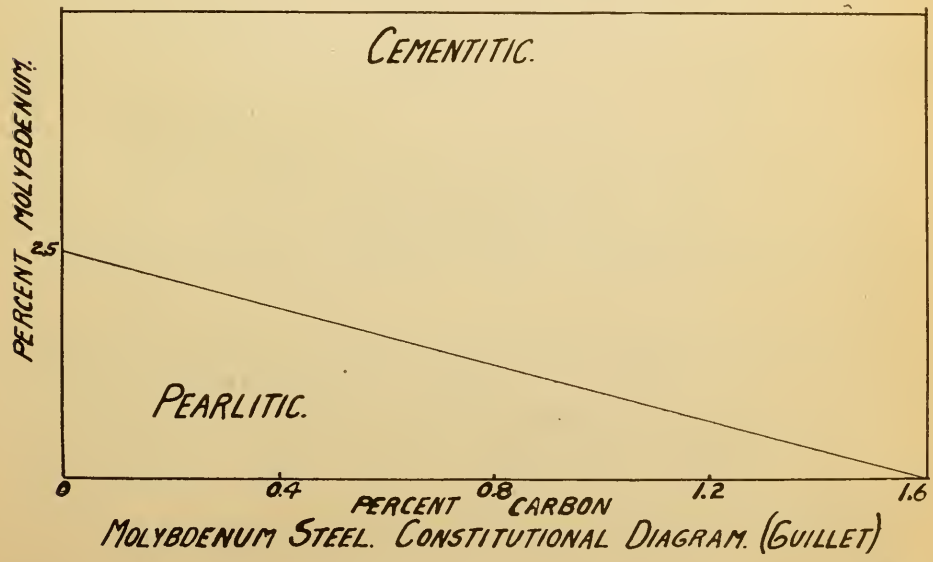


Fig. 12—Constitutional Diagram for Molybdenum Steels —*Guillet*

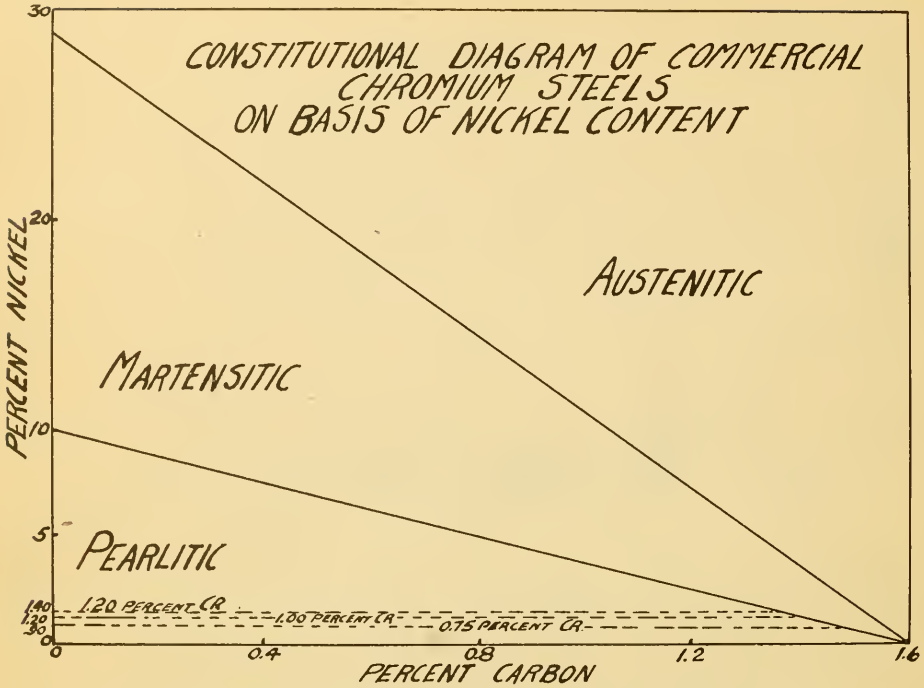


Fig. 13—Constitutional Diagram for Commercial Chrome Steels. (Nickel Basis)

the pearlitic type. That is, there is not enough of the special element or elements and carbon to place them out of the pearlitic zone. This means, therefore, that on slow cooling the carbon would be in the pearlite. To be sure rapid cooling would enable the production of sorbite, troostite, martensite or austenite, the constituent formed dependent upon the rate of the cooling; but this possibility would in no wise take them out of the pearlite class. Plain carbon steel can be so treated as to produce these same constituents, but no one would proclaim such a steel as anything but pearlitic.

Charts have been prepared for our common structural and fabricating steels, on the basis of nickel so that they might be viewed from a common plane. Practically speaking, there are but few structural or fabricating alloy steels with more than 0.45 per cent carbon. Most of these steels have such comparatively low percentages of the special element or elements that the type of steel would remain pearlitic with a carbon content of 0.80 per cent and in many cases, even, with a higher carbon content.

In Fig. 5 the straight constitutional diagram for nickel steel is given. Note that with but a trace of carbon the steel would remain pearlitic until 10 per cent of nickel were present. In Fig. 6 two grades of nickel steels are set into the regular constitutional diagram for nickel steel. These grades are the 2.0 per cent nickel and 3.5 per cent nickel steels. The nickel content is so low that for all of the amounts of carbon customarily used the steels remain pearlitic.

In Figs. 7, 8 and 9 are given some of the nickel-chrome (1.25 per cent nickel and 0.60 per cent chrome, 1.75 per cent nickel and 1.10 per

cent chrome, 3.00 per cent nickel and .80 per cent chrome, and 3.50 per cent nickel and 1.50 per cent chrome), chrome-vanadium (0.95 per cent chrome and 0.18 per cent vanadium), and chrome-molybdenum (0.95 per cent chrome and 0.35 per cent molybdenum, 0.95 per cent chrome and 0.65 per cent molybdenum, and 0.95 per cent chrome and .90 per cent molybdenum) steels.

The special elements in these steels are all converted to a nickel basis. Thus, since in nickel steels with only a trace of carbon 10 per cent of nickel would be required to take it out of the pearlitic class and since in chrome steels Fig. 10, 8 per cent of chrome would take this steel out of the pearlitic class chromium is assumed to be 10/8 or 1.25 times more powerful in this particular function than nickel. In the same way 1.0 per cent of vanadium, Fig. 11, may be said to compare with 10 per cent of nickel. Thus the conversion factor for vanadium is 10. In like manner

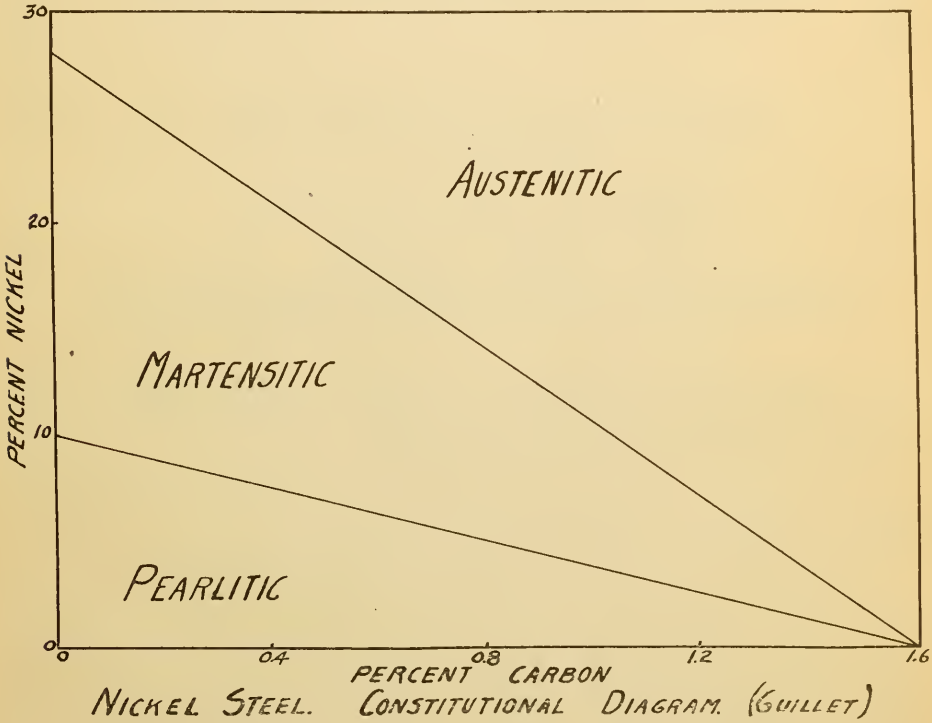


Fig. 14—Constitutional Diagram for Commercial Silicon-Manganese Steels. (Nickel Basis)

the conversion factor for molybdenum, Fig. 12, is 4. That is, from this particular view point 2.5 per cent of molybdenum may be assumed to be the equivalent of 10 per cent of nickel.

In Fig. 13 is given three of the commercial chrome steels (0.75 per cent chrome, 1.0 per cent chrome and 1.20 per cent chrome) converted into terms of nickel.

Fig. 14 gives two of the so-called silicon-manganese steels (1.65 per cent silicon and 0.70 per cent manganese, and 1.95 per cent silicon and 0.60 per cent manganese) converted to terms of nickel. The factor for silicon, Fig. 15 is 2. No account of the manganese has been taken for

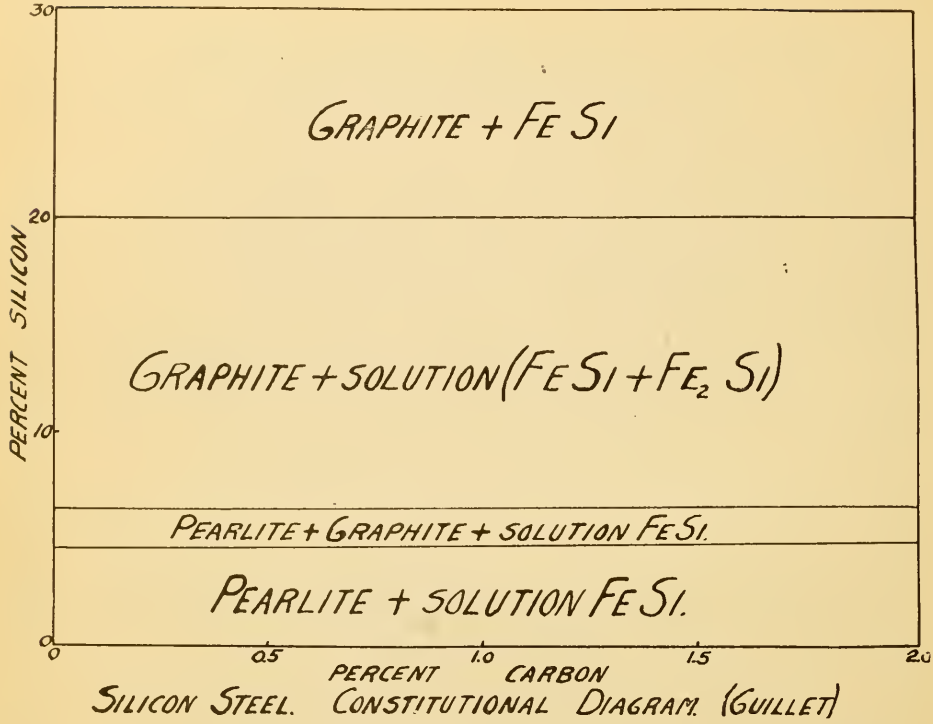


Fig. 15—Constitutional Diagram for Silicon Steels —*Sauveur*

it is not in quantities appreciably above those ordinarily found in alloy steels. Why these steels should be spoken of as silicon-manganese is not clear. They are essentially silicon steels.

A grade of steel known as magnet steel—essentially a chrome low tungsten product—converted into terms of nickel (See Figs. 10 and 16) is given in Fig. 17. The conversion factor for tungsten is 1. As previously mentioned the conversion factor for chromium is 1.25.

No claim is made that the heat treatment is the same for any of the alloy steels of the same carbon content with the same nickel equivalent content. Nor are conditions necessarily the same with respect to quenching mediums, time at heat, and other matters of a like character. The point which it is desired to emphasize is that all of the commercial structural and fabricating alloy steels are essentially of a type known as pearlitic; and the general laws—with proper variations to be sure—which apply to straight carbon steel with reference to heat treatment apply to these steels.

An alloy steel which seems to have excellent possibilities for rails but which has not been considered essentially a structural or fabricating steel is the manganese steel. It is usual for the manganese to be between 12 and 14 per cent. These amounts combined with the carbon make it an austenitic steel. As a steel it is so tough that it can be machined only with difficulty and therefore can find use only in parts not requiring that operation. Its constitution is given in Fig. 18.

In passing high speed tool steels should be touched upon. They are essentially composed of 18 per cent tungsten, 4 per cent chromium, and

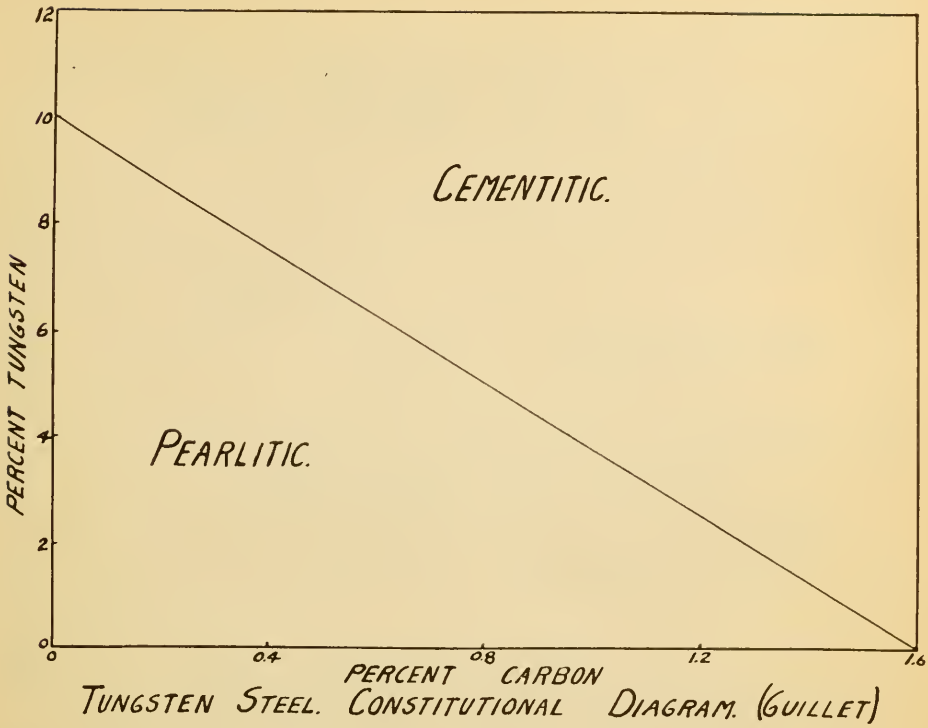


Fig. 16—Constitutional Diagram for Tungsten Steels —*Sauveur*

1.75 per cent vanadium. On the basis of tungsten, the chromium factor is 1.25 and the vanadium factor is 10. See Figs. 10 and 11. Thus a steel of the above composition, as shown in Fig. 19, has a tungsten equivalent of 38 per cent. This high percentage places it beyond all question in the cementitic class.

In the selection of any grade of steel there are numerous factors to be considered. Pre-eminent among these is cost. In the past there has been too much emphasis placed upon first cost and too little upon ultimate cost. Thus one grade of gear steel may cost 12 cents a pound and another grade 10 cents a pound. The lower priced steel may be selected and if used in a gear weighing 10 pounds, there may be an apparent saving of 20 cents per gear. Assume the cost of each gear up to inspection after heat treatment is $15.00, for the gear made of the lower priced steel and $15.20 for the gear made of the higher priced steel. Assume the scrap loss on the gear made of the lower priced steel is 5 per cent and on the gear made of higher priced steel is 2 per cent. Assume 200 gears are made per day. Under these conditions the cost of each acceptable gear made of the lower priced stock after heat treatment is $15.73, and of each gear made of the higher priced stock $15.49; a saving through the use of the higher priced stock of $48.00 per day or of $14,400 per 300-day year. Quality is not always a matter of price, though usually it is. The illustration is given not for the purpose of blindly proposing the use of high priced stock but for the purpose of pointing out that at times the higher priced stock may prove to be the cheaper.

Another vital factor is its cleanness, uniformity, and freedom from

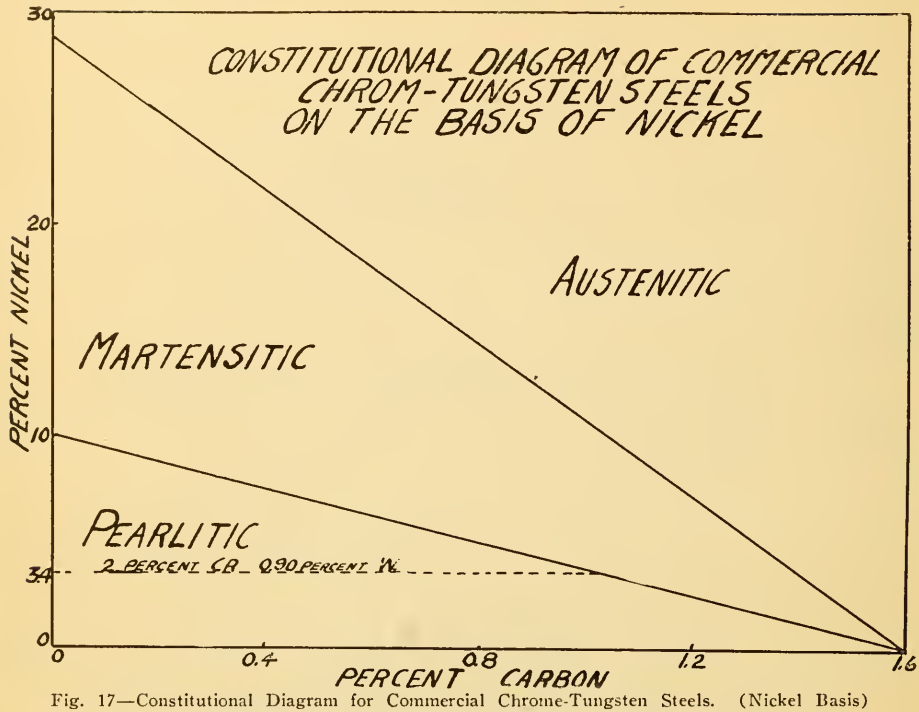


Fig. 17—Constitutional Diagram for Commercial Chrome-Tungsten Steels. (Nickel Basis)

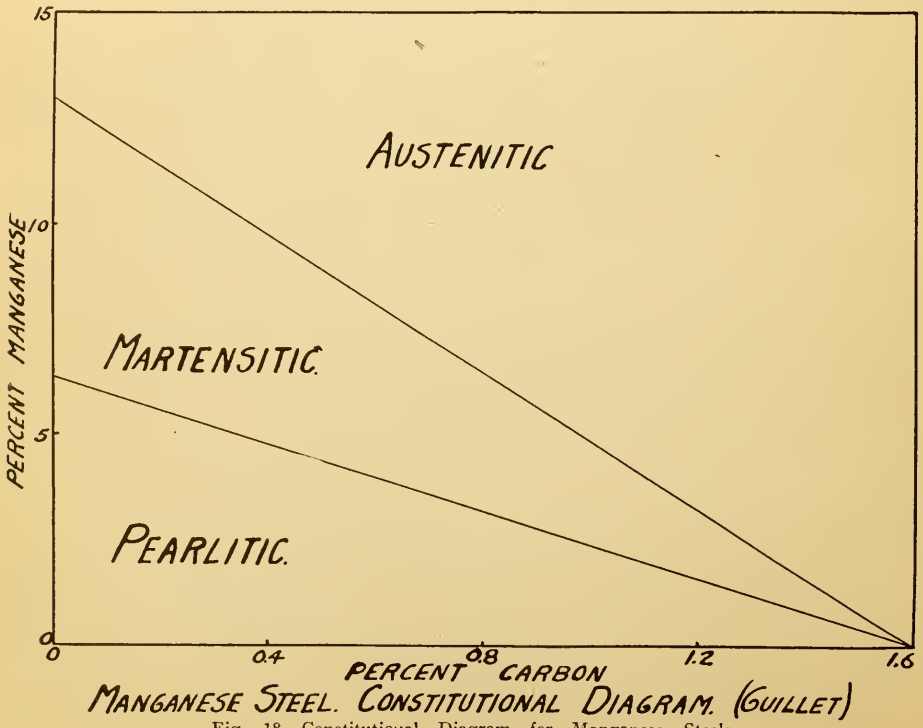


Fig. 18—Constitutional Diagram for Manganese Steels

surface and internal defects. These are conditions that the mill producing the steel has in its control. In an attempt to make tonnage records, satisfy stockholders, and purchasing agents the quality of all alloy steel has not, in all cases, been as high as we would like to see. To be sure, within the past few years, purchasing agents have not been able to be overly deliberate in the purchase of steel. The demand for finished automobiles and other machines and apparatus using alloy steel has been so great that purchasing agents have taken what they could get. To meet the pressure placed upon them some mills, in fact all mills, have been tempted to lower standards of quality. That period, at least for the present, is past.

Influenced, the author believes, by just such a set of conditions as

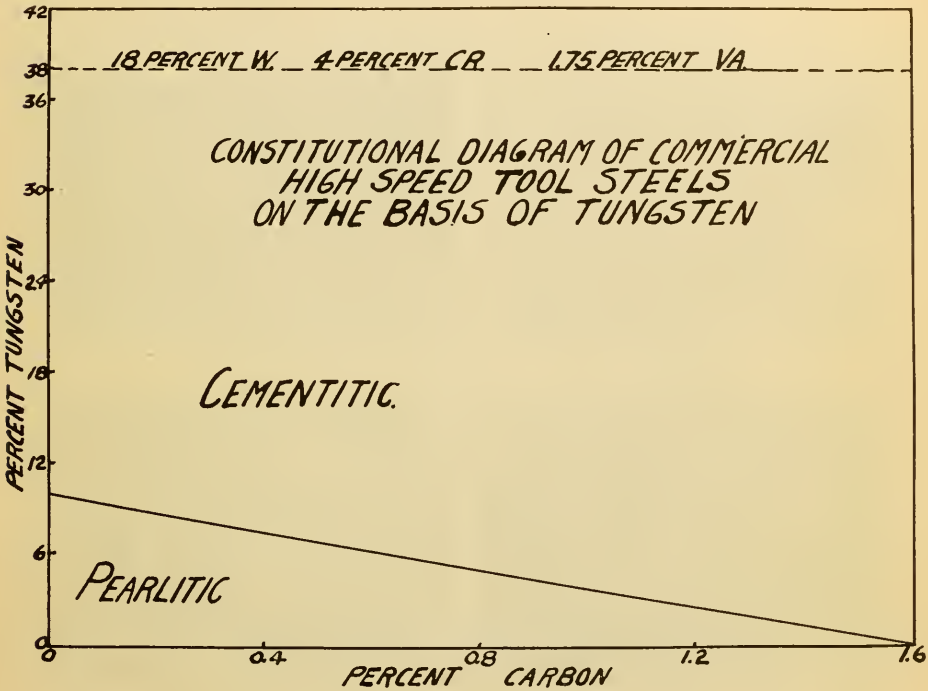


Fig. 19—Constitutional Diagram for Commercial Chrome-Tungsten Steels. (Tungsten Basis)

has been stated, one of the prominent metallurgists in the country has tended to turn toward plain carbon steel in place of the alloy steel used in the plants under his control. On the assumption that piped alloy steel is not much, if any, better than plain carbon steel, his stand is right. On the assumption that beginning with 1921 we may except to be able to buy alloy steel with practically full assurance regarding its freedom from piping, undue segregation, and surface defects, his position is wrong.

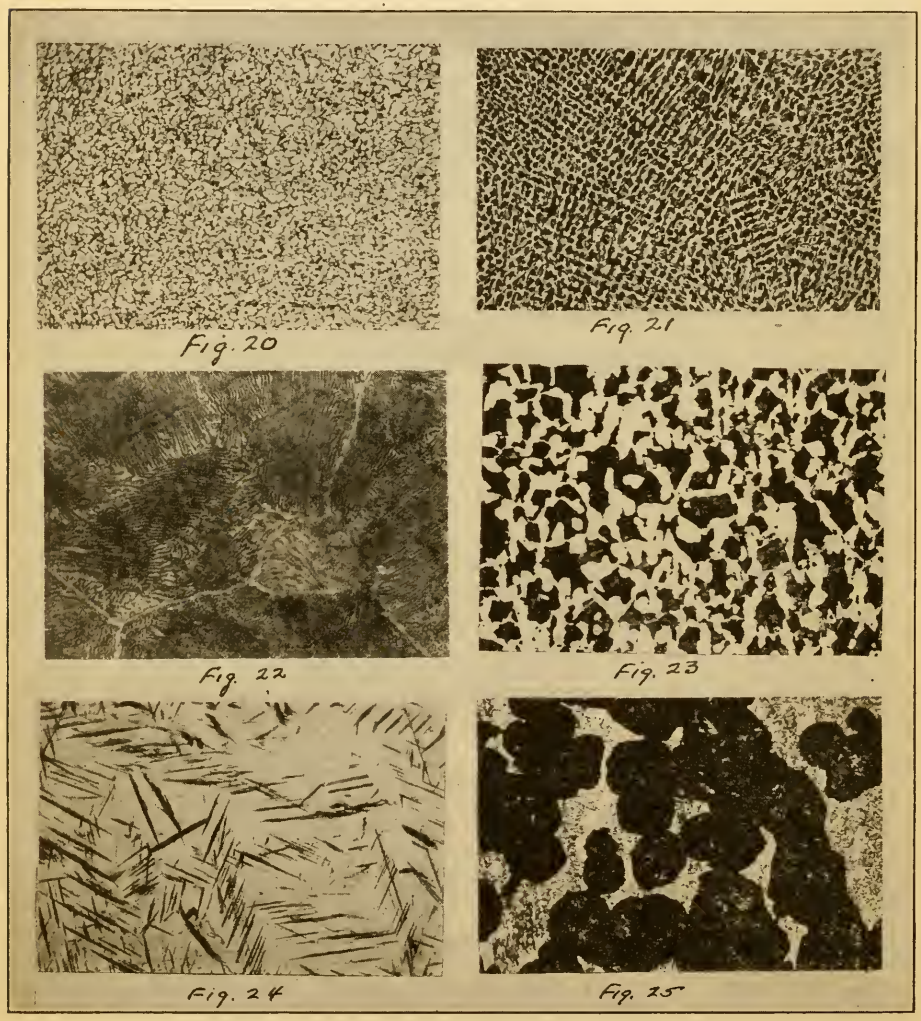
The statements just made are not a charge against our mills producing alloy steel. Such conditions as are wrong are chargeable to ourselves. Last summer those of us that were in the market for cars were placing all kinds of pressure upon the agents. They transmitted this pressure to the factories, and from there it was passed on. What is surprising, is that the quality of steel remained at such a high standard in spite of this pressure.

Factors of importance to the fabricator are ease of forging, ease of

machining and fool proofness in heat treatment. In this last field resistance to warping, resistance to the development of quenching cracks, a wide quenching range and a high drawing range are most desirable.

Finally, a factor so self evident that it has been left to the last is the ability, after suitable treatment, to get the desired properties. It is this last factor, the ability to cut down weight and retain strength, maintain strength with no sacrifice in ductility, increase hardness, increase resistance to shock, increase resistance to fatigue or to secure some other type or set of properties that has brought the special structural and fabricating alloy steels into such general favor and use.

Those who use alloy steel have, as a rule, definite ideas regarding



Photomicrographs of Steel Showing Various Constituents. Fig. 20—Largely Ferrite. Fig. 21—Cementite (White). Fig. 22—Pearlite. Fig. 23—Sorbite (Black). Fig. 24—Austentite (White) and Martensite (Dark). Fig. 25—Martensite (White) and Troostite (Dark).

the types they favor. It is surprising, though, that even with the large number of tests which have been made, and which are daily being made, no one class stands out as the type for a particular service. Possibly, on reflection, this condition should be true for differences in design, in manufacturing operations and sequences may, quite logically, call for different types.

A disappointing feature of the whole situation, however, is the absence of correlated data for the various types. Each individual plant using alloy steel may feel that it has such data but there are many plants whose sole reason for the use of a given steel is familiarity and relative acceptability in service. These, it is granted, are strong reasons and should not be thrust aside until after due assurance that a change will either lower costs, improve quality, or, possibly, accomplish both results. It is disappointing, though, to find plants that can speak only in generalities. It is unfortunate that they do not have concrete evidence to support their choices.

Much data which has been secured in the past is of little value because the conditions under which it was obtained were not the same. The manner in which the steel is made, the amount and the nature of the mechanical work done upon the metal and the temperature at which such work is done, the location of the test section in the ingot or bar, the size of the test bar and whether it is heat treated in the rough, in the semifinished or finished condition, the character of the finish machining upon the bar, the method of heating, including time in furnace, location in furnace and character of furnace gases whether neutral, reducing or oxidizing, the location and correctness of the pyrometer, the time of transference from the heating furnace to the quenching bath, the shape and size of the bath, the nature and temperature of the quenching medium, differences in drawing and differences in calibration and speed of operation of testing machines are all factors which play an important part in the properties obtained in the steels. The normal instruction of quenching a bar 0.505 inch in diameter in oil at 1450 degrees Fahr. and drawing at 900 degrees Fahr. does not tell all the story. It is because this is true that the discrepancies which crop up from time to time in steels of the same grade make their appearance.

The Society for Automobile Engineers is today engaged in a splendid piece of standardization along the lines just pointed out as being so badly needed. It is trusted that they may continue to make the progress which has been so auspiciously started.

As a final word we find in Ecclesiastes XXXVIII, 28, the following paragraph:

"The smith also sitting by the anvil, and considering the iron work, the vapour of the fire wasteth his flesh, and he fighteth with the heat of the furnace: the noise of the hammer and the anvil is ever in his ears, and his eyes look still upon the pattern of the thing that he maketh; he setteth his mind to finish his work, and watcheth to polish it perfectly."

It is that last word "perfectly" which should be our goal. Whether we are makers of steel, sellers of it or of allied products, consumers of it, or fabricators and heat treaters of it, let us approach it with a full understanding and in our contact with it do our part "perfectly."

MOLYBDENUM STEEL AND ITS APPLICATION

By M. H. Schmid*

(A Paper Presented Before the Washington Chapter)

While it is true that molybdenum structural steels were commercially developed during the world war, and through their development rendered possible great advancement in army and navy equipment and accessories, it is equally true that war conditions merely furnished the impetus for this development. The commercial application of molybdenum steels for industrial purposes was inevitable; the assurance of adequate and accessible domestic supply of this important alloying element allaying all fears as to the ability to meet future commercial demands.

That the earliest experiments in molybdenum steels were confined largely to tool and magnet steels is not surprising in view of the fact that molybdenum was not then known to exist in sufficient quantities to warrant its consideration, other than purely academic interest, for commercial structural requirements. It is surprising, however, to note that in spite of the then limited available supply of this alloying element, the earlier experimentation on structural steels was in most cases confined to material of a much higher molybdenum content than is considered advisable at the present time. It is also surprising that practically all study was confined to its direct effect in the ternary steels instead of more research on its indirect effect or additive and intensifying effect on other elements in the quartenary and more complex alloy steels. It is of course quite possible that research along the latter lines was pursued but not published. It is a fact, however, that exhaustive research directed by C. H. Willis established the practicability of the commercial application of molybdenum as an alloying element in the various types of alloy steels.

A review of the many types of steel on which the addition of molybdenum has a distinctly pronounced beneficial effect enables us to grasp the diversity of the application of molybdenum steels. Its effect is pronounced in straight carbon steels, chromium steels, nickel steels, chrome-nickel steels and vanadium steels. In straight carbon or nickel steels, by uniting with the ferrite additional strength is imparted without corresponding decrease in toughness. In steels containing chromium, probably through the formation of double carbides, additional strength and hardness is imparted together with beneficial effect due to any diffusion in the ferrite. The penetrative effect of heat treatment, especially in large sections, is decidedly pronounced.

I think most of us can recall the time when the selection of alloy steels for various products was based almost entirely on the physical characteristics obtainable. There is now a variety of types of alloy steels in which there is very little difference in physical properties, all of which will yield the necessary strength and factors of safety in the finished product. The present consumer of alloy steels, having at his command many types that are satisfactory so far as static and dynamic qualities are concerned, is influenced in his choice of material by the efficiency of the product in proper and economical functioning in the various manufacturing processes. From the manufacturing standpoint, he wants a steel which first of all has a tendency toward the minimum of inherent defects; he wants a steel which gives the most efficient response to the various thermal and mechanical manipulations to which it is subjected

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in the numerous stages of processing from the raw material to the finished product.

Careful consideration of the following requirements should be given by the customer in his selection of an alloy steel:

(1) It shall meet such specifications as are imposed by the engineering department.
(2) The elements used in its manufacture shall be readily obtainable with assurance of adequate source of supply for the future.
(3) It shall not be subject to patent litigation.
(4) It must be entirely practicable as a commercially manufactured product of uniform quality.
(5) It must respond satisfactorily to various thermal manipulations with reasonably wide temperature ranges.
(6) It must respond satisfactorily to various mechanical manipulations.

We will not review these requirements in detail from the standpoint of molybdenum steels.

(1) *Specifications.* There is little need for a detailed discussion regarding physical characteristics. "Molybdenum Commercial Steels" published by the Climax Molybdenum Co. gives concise information as to just what physical properties may be developed on the various types of molybdenum steel. We know that the chrome-nickel-molybdenum steels used on Liberty motors for aircraft service met the most exacting specifications and records of tests on physical properties showed results superior to those obtained on any other types of steel used in this class of work. As far as the desired physical properties are concerned, it appears but necessary to select the particular type best suited for the purpose under consideration. For general requirements for automotive or machine construction, the chrome-molybdenum steels are usually recommended for special requirements it becomes necessary to use the more complex types, such as chrome-nickel-molybdenum.

(2) *Raw Materials.* The supply, present and future, of ferro-molybdenum for commercial production has been assured. Sufficient ore deposits, adequate for many years production have been established, with the necessary mining and refining capacity to take care of all future requirements. Four-fifths of the world's known available supply of molybdenum is contained within the borders of the United States. The present supply of chromium, the alloy most commonly used in connection with molybdenum is practically inexhaustible and is found in most every part of the world.

(3) *Patents.* The recent action whereby any alloy steel manufacturer in the United States may be licensed to produce chrome-molybdenum steels under patents during the life of same on a royalty basis which is so trivial as to have no bearing on the price of the steel, should relieve any fear as to litigation.

(4) *Manufacture.* That the manufacture of molybdenum steels is on a practical commercial basis has been well established. The first heat of electric furnace steel made by the United Alloy Steel Corp. was tapped Dec. 3, 1917, since which time this company has made in excess of 10,000 tons of ingots of various types, comprising carbon-molybdenum, chrome-nickel-molybdenum, etc. The first open-hearth heat of molybdenum steel was tapped by this company May 24, 1918, and since that time approximately 25,000 tons have been produced.

No serious difficulties are experienced in the various stages of proc-

essing, from melting and casting on through the rolling and cold drawing operations. The manufacture of molybdenum steel merely requires the same care as is exercised in the production of any well made type of alloy steel of similar potential properties—in fact less care than is necessary on many types.

Molybdenum is available as a furnace addition in two forms, as ferro-molybdenum and as calcium molybdate. In the ferro form it is most conveniently obtained and used with a molybdenum content of 50 to 60 per cent, although our company has very successfully used 70 to 80 per cent ferro-molybdenum. In the form of calcium molybdate we have a lower percentage of metal, averaging 35 per cent. The ferroalloy may be added in the open-hearth process as follows:

(1) All additions in the furnace as the charge is melting down.

(2) All additions in the furnace just prior to tapping (10-15 minutes).

(3) All additions in the ladle.

(4) Part addition in the furnace and part in the ladle.

In the manufacture of molybdenum steels at our plant we have thoroughly investigated all of the above methods and have adopted the first as standard practice because of the better diffusion and higher degree of uniformity in the finished product together with higher efficiency or minimized loss of the alloy.

It has been our experience that calcium molybdate is most satisfactorily added in sacks as the scrap charge is melting down, being so placed as to permit the partially molten scrap to cover or envelop the salt. Greater care is necessary with calcium molybdate than with the alloy in ferro form in order to prevent the draft of the furnace from pulling off part of the powdered molybdate addition and carrying it to the furnace walls, ports and checker chambers. The average loss of metal added in ferro form by the first method outlined above should not exceed 5 to 10 per cent, the loss tending toward the minimum where the same furnace or furnaces are used on successive heats, thereby reducing the purely mechanical loss. Just how this loss may be subdivided is worthy of some discussion. A slight mechanical loss is inevitable and we may assume it as running between 2 and 4 per cent, leaving an additional loss of say from 3 to 8 per cent unaccounted for. The author is not prepared to state just how this should be distributed. It is probably due to both oxidation and volatilization. Molybdenum additions in the ladle are generally inadvisable and where a high molybdenum content in steel is required, should be made only in the molten condition.

Of worthy consideration is the utilization of molybdenum steel scrap, which may be included in the furnace charge with a yield of approximately the same ratio as direct alloying additions.

No special comment is necessary regarding ferro-molybdenum and calcium molybdate charges in the electric furnace, where slagging, oxidizing and temperature conditions are under absolute control. Practically one hundred per cent alloy efficiency is possible.

The blooming and finish rolling operations on molybdenum steel require no special precautions other than those necessary on corresponding types of other alloy steels, and the practice, measured in per cent of available finished product, is higher than in most types of similar properties. The tendency toward a minimum amount of inherent defects, both

surface and subsurface, is very pronounced especially as compared with nickel and chrome-nickel steels.

While molybdenum evidently has no deoxidizing or scavenging effect, it has at the same time no deleterious effects on the working of the steel and a chrome-molybdenum steel should process as efficiently as the same type without molybdenum, and a chrome-nickel-molybdenum should process as efficiently as the same type without this additional alloy. Molybdenum steels as a class may be considered as more free from seams than nickel and chrome-nickel steels of corresponding potential values. It would be absurd, however, to claim that such defects in billets heal up or roll out in finishing mill operations.

Wide temperature ranges are available for rolling and forging, and while there is no appreciable difference in the amount of scalage, there is a marked advantage in the texture of the scale over that on nickel steels. The scale is a loose, nontenacious one, freely flaking from the steel showing no tendency to roll into the surface and result in pitting.

(5) *Thermal Manipulations.* Molybdenum steels as a class may be subjected to unusually wide temperature ranges for both hot working and heat treating. This applies particularly with respect to the more generally used chrome-molybdenum types which will satisfactorily withstand considerably higher temperatures than the corresponding types of nickel and chrome-nickel steels. Forging companies report that chrome-molybdenum steels flow better in the dies than other types, which advantage is probably due to a large extent to the use of higher working temperatures. The author cannot conscientiously credit molybdenum steels with less scalage loss, but it is certainly true that less difficulty is encountered in forging operations on account of the ease with which scale loosens from the bars in carbon-molybdenum and chrome-molybdenum types. Cleaner forgings are obtained and tumbling and pickling charges are minimized.

The outstanding features relative to the heat treatment of molybdenum steels are the extremely wide quenching ranges available for practical heat treatment; the excellent penetrative effect of such treatment on large sizes; and the broad drawing range causing but slight modification in physical properties, this due to the retarded disassociation and reversion to normal state upon heat application after quenching. Data has been published by the Crucible Steel Co., the Carbon Steel Co. and the United Alloy Steel Corp., showing uniformity in static properties through a wide range of quenching temperatures, but without information as to comparisons on dynamic properties.

To show that impact as well as static properties evidence no marked variation with quenching temperatures ranging from 1500 to 2000 degrees Fahr. inclusive, I have taken average results from a series of recent experiments in our laboratories on chrome-molybdenum steel analyzing as follows: Carbon, 0.27; manganese, 0.66; sulphur, 0.036; phosphorus, 0.018; silicon, 0.08; chromium, 0.83; molybdenum, 0.42 per cent. The size treated was 7/8-inch round and all tests were drawn at 1050 degrees Fahr., after quenching in water at the temperature indicated. The tests were as follows:

Quenching Temperature Degrees Fahr.	Elastic Limit pounds per square inch	Tensile Strength, pounds per square inch	Elongation, per cent	Reduction of Area, per cent	Brinell	Izod
1500	140,000	163,500	18.5	62.7	319	58
1600	139,500	161,700	17.0	63.1	321	62

1700	138,400	160,400	17.5	61.7	321	60
1800	138,300	158,500	18.0	61.5	319	61
1900	139,600	159,600	16.8	57.9	317	56
2000	140,000	157,000	17.0	59.0	317	55

Striking evidence of the penetrative effect of treating as well as the high drawing temperatures available for attainment of high physical properties is manifested in our type "LM", chrome-nickel-molybdenum steel, used for crankshafts and connecting rods in aircraft work. The analysis range of this type is: Carbon, 0.22-0.30; manganese, 0.50-0.70; sulphur, 0.035 maximum; phosphorus, 0.030 maximum; silicon, 0.10-0.20; chromium, 0.70-0.90; nickel, 2.75-3.25; molybdenum, 0.30-0.50 per cent. Heats running 0.25-0.30 per cent carbon were selected for crankshafts, and those running 0.22-0.25 were used for connecting rods. Physical results taken on a full size prolongation, approximately 4 inches diameter, and averaged from 28 tests taken at random showed:

Elastic Limit: 130,000 pounds per square inch.
Ultimate Strength: 142,000 pounds per square inch.
Elongation in 2 inches: 20.5 per cent.
Reduction of area: 65.0 per cent.
Izod: 67.
Brinell: 303

On a series of tests on 2 inches round, taken from the same type, after quenching in oil at 1450 degrees Fahr. and drawing as indicated, were obtained:

Drawing Temperature, degrees Fahr.	Elastic Limit pounds per square inch	Ultimate Strength pounds per square inch	Elongation per cent	Reduction of Area, per cent	Brinell	Scleroscope
500	233,000	249,800	14.0	46.8	455	54
900	170,000	189,200	16.0	51.6	363	45
1000	161,000	180,700	18.5	58.3	344	43
1100	149,000	166,800	18.5	60.0	328	41

These results show that there is but slight change in physical characteristics between the 900 and 1100 degree Fahr. drawn.

On type "Mo. 102", an oil hardened gear steel, were obtained a tensile strength in excess of 200,000 pounds per square inch for all drawing temperatures up to 1000 degrees Fahr., and an elastic limit in excess of 200,000 pounds per square inch for all temperatures up to 900 degrees Fahr. Tests on standard 0.505-inch specimens, quenched in oil at 1450 degrees Fahr. and drawn at 400 and 1000 degrees Fahr. respectively, gave:

Drawing temperature, degrees Fahr.	Elastic Limit pounds per square inch	Tensile Strength pounds per square inch	Elongation per cent	Reduction of Area, per cent
400	302,000	336,600	10.0	22.4
1000	190,000	202,200	15.5	50.1

(6) *Mechanical Manipulations.* The most important mechanical operations to which steel is subjected in the manufacture of the finished product are cold pressing, forming and heading, and machining. Efficient response in the operations involving cold flowing of metal effects savings in fabricating costs resultant from minimization of rejections in semi-finished and finished parts, as well as maintenance costs on dies and tools. The merits of molybdenum steel for this purpose have been established through the results obtained on carbon-molybdenum and chrome-molybdenum types in the cold forming and pressing operations in the manufacture of automobile frames, die steel wheels and rear axle housings;

through production of cold headed parts on the chrome-molybdenum types, and through cold upset balls on the high carbon, chrome-molybdenum ball and race types

The molybdenum steels have better machineability than other alloy steels of equal physical properties. This has been established by the production results obtained on several thousand tons processed into rear axle drive shafts and on which no machining difficulties were experienced on shaft heat treated to conform to a 300-340 Brinell specification. On a heat made by the United Alloy Steel Corp. for one of the large automobile companies and put into steering knuckles and front axles, a report was received to the effect that tool grinding costs were but one-third as high as on 3½ per cent nickel steel of the same hardness and with corresponding shop production. Front axles with Brinells up to 340 maximum machined as well as chrome-nickel steel axles of 302 Brinell.

The scope of application of molybdenum steels appears wider than that of any of the other types of alloy steels. While the greater portion of the molybdenum steel manufactured to date has been used in automotive forgings and pressed metal parts, its excellent properties have likewise warranted its use in a variety of other parts, embracing railroad forgings and track bolts, armor plate, air flasks, agricultural implements, shovels, machinery forgings and piston rods, various edge tools, etc. The general utility of molybdenum steels promises an increased demand in a well diversified field.

THE ESSENTIALS OF MODERN PYROMETER EQUIPMENT

By H. G. Hall*

(A Paper Presented by Title at Philadelphia Convention)

In a pyrometer steel treaters have been asking for an instrument that is accurate, but the tendency seems to be to sacrifice considerable in the other features to obtain accuracy. While it is admitted that accuracy is of prime imporance, other features are to be considered. The subject naturally divides itself into three distinct parts: (1) The instruments; (2) the leads and (3) the thermocouples. It has been found that the instrument to give the most satisfactory results should have a resistance of about 250 ohms across binding posts. This is for plant use of course and seems high enough to eliminate the troubles due to changes of external resistance. Careful tests have shown that just as accurate results can be secured with this amount of resistance as is found in the higher resistance meters, thus it is not necessary to sacrifice further ruggedness for the additional ohms resistance.

The indicating instrument should have a very clear and readable scale, instruments supplied with a spotter being advantageous for shop work, particularly when the temperature is to be maintained constant. An instrument void of chamber error certainly is one of the very important features to be remembered in making the selection because of the fact that some meters have a chamber error amounting as much as 40 degrees which makes them useless to the steel treater.

The discussion might be carried further as to whether the instrument should be of the suspension type or of a double or single pivot movement. The fact is, that it is necessary to have an instrument that will stand the ordinary amount of vibration found in a shop. The highest grade of double pivot movement has answered the requirements very

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well as it seems to be least affected by vibration. Careful tests show that this type of instrument gives the desired degree of accuracy.

The chamber error has been found to be one of the important causes for trouble. This is a very annoying situation because many do not know what is causing the inaccuracy and it is difficult to correct without replacing the meter.

While the recording type instrument is used in some cases as an indicator as well as a recorder, the most important factor is simplicity of design. It must at the same time make clear and readable records. Obviously, a steel treater does not want a recorder that will require constant supplying of repair parts and in this way, take his attention from other work, which involves considerable annoyance and added expense.

It has been found that recorders giving the continuous automatic records are to be preferred to those that give numbers from which the curve can be drawn later. The charts made should be easy of access and easy to file, thus the principal feature in connection with the use of the recording pyrometer should be simplicity of construction. Surely the simplest mechanism, other parts being equal, will require the least care and the least amount of rechecking.

In considering leads or couple extensions one must consider the proper kind of insulation for the wire to meet the plant conditions. In many cases it is necessary to use asbestos-covered wire where rubber-covered wire would not be satisfactory, and vice versa. The couple extension is one of the important features of every pyrometer equipment. A number of steel treaters using pyrometers have installed in their plants what are called "compensated leads" although the term is not commonly understood.

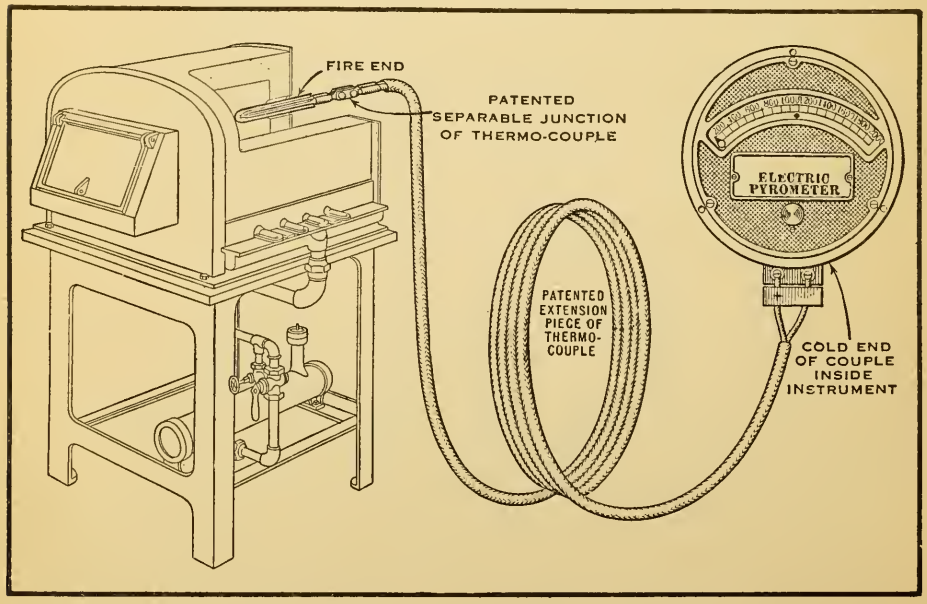


Fig. 1—Diagram of a Pyrometer Installation Showing the Fire End of the Thermocouple Inserted in the Furnace

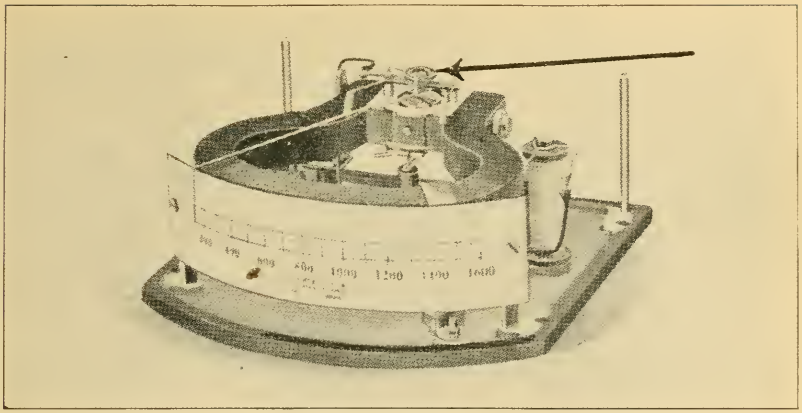


Fig. 2—Interior View of a High-Resistance Indicating Pyrometer Showing the Compensator Denoted by Arrow

Certainly this term should be defined clearly thus possibly the term flexible couple extension carries the idea more clearly than compensating leads. The latter seems a misnomer because these leads do not actually compensate. This brings us to the consideration of the error due to the cold junction variation in temperature. On some pyrometer equipments the cold junction is buried in the ground and on others it is put in the hot water or steam jackets; and on still others it is put in regulating boxes controlled by lamps. Recently some steel treaters have put the cold end in a box of a special powder in which the cold end does not vary more than plus and minus 5 to 10 degrees Fahr. While it is true that these methods of installation have been satisfactory under certain conditions, they have not met the universal requirements for eliminating the error due to the cold end. It is very expensive under many conditions to bury a cold end for blasting in rocks or concrete often is required. Water jackets will leak in time and cold end regulating boxes are just an additional part of the equipment to require care. It must be borne in mind constantly in using the pyrometer that the electromotive force developed depends upon the difference in temperature between the cold junction, which is outside the furnace, and the hot junction which is in the furnace.

An internal cold junction compensator has been developed and tried which operates automatically and does away with the necessity for burying the cold end in the earth and eliminates the use of any other outside means for regulating the temperature at the cold end. It is enclosed in the instrument itself, one end of the internal spiral compensator—for such it is called—being attached to the pointer while the other end is securely fastened to the instrument. The method of using the compensator is illustrated in Fig. 1. It is satisfactory for use on either base metal or precious metal couples.

Of course, in using this compensator it is necessary to run the same kind of material that is in the base metal couple to the instrument itself. In the case of an installation of an instrument with a compensator for a manufacturer of crank shafts for automobiles, the temperature of the oven was maintained at 40 degrees Fahr. and readings were taken across the entire scale, the readings being within ¼ to 1 per cent. Many other companies are using this compensator with similar accuracy.

It is also very gratifying to find that this compensator has worked out so satisfactorily because it is the result of many years of experimentation on a suitable device for accomplishing this result. Credit for the development work is due to William H. Bristol, of The Bristol Co., Waterbury, Conn.

Elimination of the chamber error in the instrument and the error due to the cold end temperature, overcomes two of the chief objections to the use of the thermoelectric pyrometer, and makes it possible to use this instrument for very low ranges of temperature with a high degree of accuracy. Accuracy well within 1 per cent for ranges of temperature is secured over the entire scale where the maximum reading of the scale is only 600 degrees Fahr.

In cases where a previous metal couple is used, the platinum wires are not run to the instrument but substitute patent alloy wire is used that carries the cold junction to the instrument and serves the same purpose for shop use as if the platinum were used for the entire length. The steel treater interested in accurate results from his pyrometer can obtain a great deal of satisfaction in knowing that his cold end errors are entirely eliminated. In other words the equipment is operated as though it had no cold end.

The diagramatic illustration, Fig. 1, shows a "fire-end" or thermocouple in a furnace, a length of flexible extension of the same material as the thermocouple extending to and inside of the indicating instrument. Fig. 2 is an interior view of a high-resistance indicating pyrometer, and shows the spiral of differential thermostatic metal which acts through the control spring of the indicating power and automatically changes the ten-

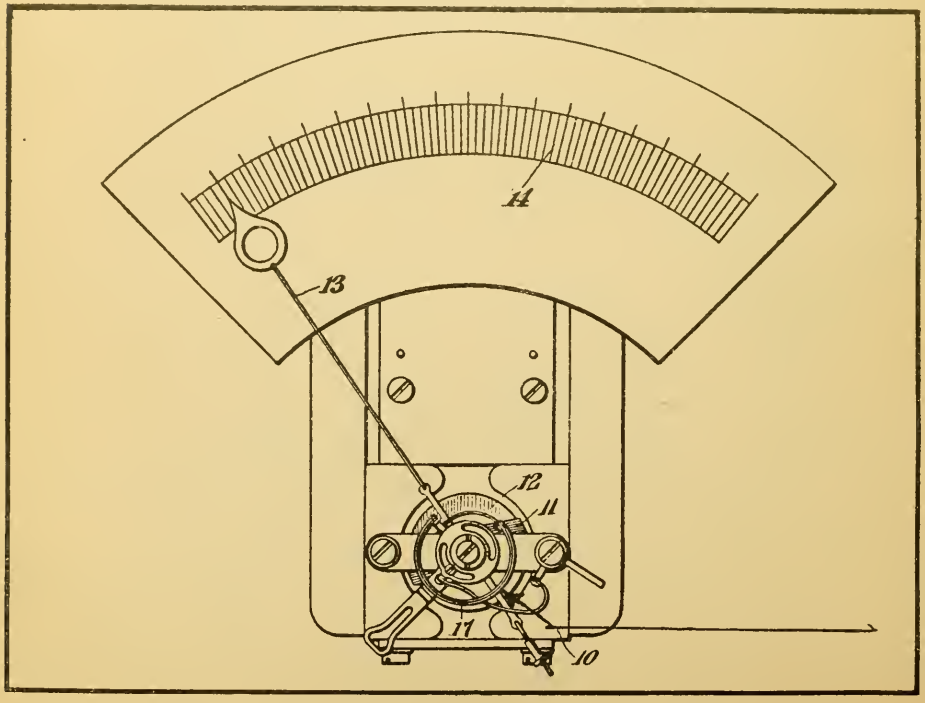


Fig. 3—Details of the Compensator Construction with Arrow Pointing to Compensator

sion on this spring so that the position of the indicating arm will continually correspond with the graduations on the scale and at the same time agree with the temperature changes of the room.

In Fig. 3 the details of construction of the compensator are more clearly shown. The indicating arm 13 is operated by the usual moving coil 11. A small portion of the control spring 12 is shown, but instead of the end of this spring being secured to the abutment, it is attached directly to the end of the spirally curved piece of thermostatic metal 17 and the other end of this thermostatic coil is carried by an adjustable abutment allowing for initial adjustment of the indicating pointer, to make its position on scale agree with that of room temperature.

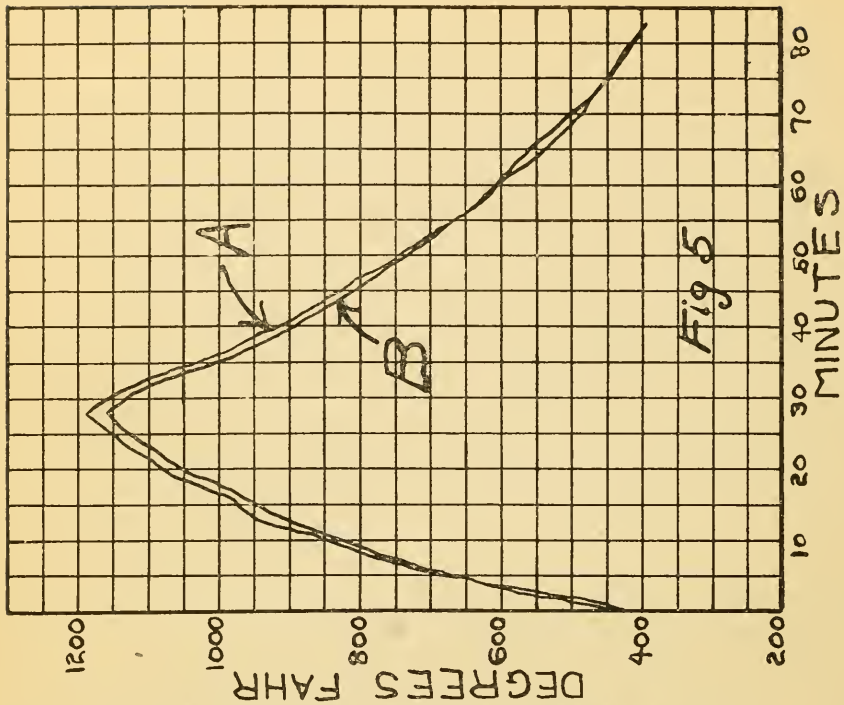
The temperature variations of the room cause the thermostatic spiral to wind up or unwind, maintaining the correct position of the indicating arm, regardless of room temperature. When the thermoelectric couple with extension-piece, as illustrated in Fig. 1, is carried into the compensated instrument, no corrections are necessary for the thermocouple cold end temperatures at any point on the scale. The compensator also may be made to serve a double purpose, since by a slight variation of its length it may be made to correct automatically for the temperature coefficient of the wire forming the moving coil of the millivoltmeter.

Fig. 4 shows curves *A* and *B* and is a comparison of readings of a laboratory potentiometer and a compensated pyrometer. The platinum couple was used with the potentiometer with the cold junction maintained at 32 degrees Fahr. in the bath. The temperature of cold junction of the pyrometer was maintained constant at 70 degrees Fahr. In Fig. 5 the temperature of the cold junction of the pyrometer was maintained at 130 degrees Fahr. in the oven while the cold junction of the potentiometer was maintained at 32 degrees Fahr. as in the case of Fig. 4. These readings were taken by an automobile manufacturer and illustrate the accuracy of the compensated pyromoter, the difference between the two instruments being practically constant throughout.

It is very important in the use of proper thermocouples that the couples produce the same electromotive force although the wires may be almost burnt off. Of course, in case the thermocouple does not give the same electromotive force, an error will occur in the readings, but with the advances made in manufacture of thermocouple alloys, this source of error has been overcome.

Although shunted thermocouples have been used with some success, the practice of using this idea as universal is not advisable because of the errors which are certain to result. The chief difficulty is that under most conditions the fire end is not always inserted the same distance into the furnace or tempering bath. With the advances made in developing alloy metals it has been found more practical to use base metal couples of selected material. These can be secured easily with a guarantee that readings will be within plus and minus 3 degrees Fahr.

The cost of thermocouple upkeep is, of course, important but this can be reduced very appreciably by making a thorough and careful study of the conditions. This includes study of the gases that are emitted from the fuel, as the oxidization of the steel or other articles in the furnace takes place. One prominent automobile manufacturer whose couple expense on about 500 couples constantly in use was about $1.00 per month, by very careful investigation of the conditions and proper protection of



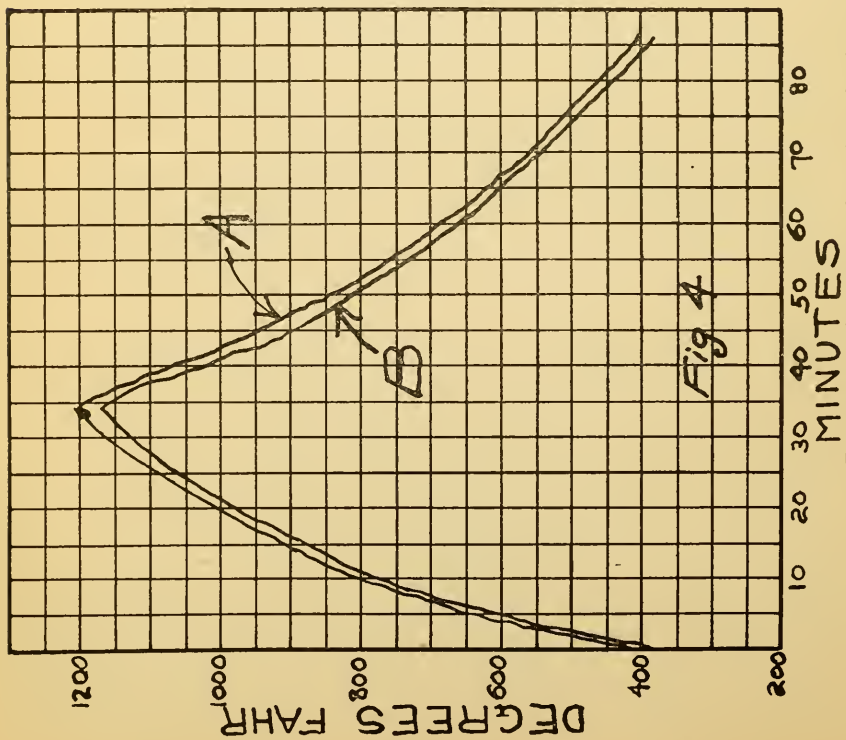


Fig. 4—Comparison Curves of Readings of Laboratory Potentiometer *A* and Compensated Pyrometer *B*. In the First Curve Cold Junction Maintained at 32 Degrees Fahr. and in Second Curve Maintained at 70 Degrees Fahr. Fig. 5—Same as Fig. 4 Except Cold Junction of Pyrometer Is Maintained at 130 Degrees Fahr. Both Fig. 4 and Fig. 5 Show an Almost Constant Difference Between the Curves

the thermocouple, reduced this cost to $0.27 a month. In this case, the manufacturer was using precious metal couples.

A manufacturer of roller bearings, who is using the potentiometer system, states that his couple upkeep was $12.00 per year, which is not excessive for platinum couples. This cost includes only maintenance expense for the couples and not the maintenance on complete pyrometer equipment whereas the case just mentioned of 27c per month includes maintenance on the entire outfit. In the former instance the upkeep of the entire equipment is included. Here the galvanomter system was used. From all the data the author was able to obtain, it is evident that the upkeep on the potentiometer systems were far in excess of the maintenance cost on the galvanometer system especially where potentiometer recorders were in use.

RELATION OF THE HIGH TEMPERATURE TREATMENT OF HIGH SPEED STEEL TO SECONDARY HARDENING AND RED HARDNESS

By Howard Scott*

High speed tool steel metallography presents certain anomalies, the explanation of which is not clear from the usual conceptions of the mechanism of hardening in simple carbon steels, as, for example, the familiar polyhedral structure of properly quenched high speed steel, which is often called austenite, although its physical properties are largely those of martensite. The explanation of such anomalies and a better understanding of the fundamental nature of high speed steel is becoming more and more important as the peak of development is being reached. It is even probable that future improvements will be largely in the technique of treatment and the adjustment of compositions to meet special requirements, in which cases fundamentals are of highest importance.

From this angle the problem of developing high speed steel is one of constitution and not composition. In spite of a wide variety of compositions, the general characteristics are very similar. The most effective method of attack, therefore, is through the study of a number of the physical properties of a high speed steel and their correlation with the corresponding characteristics of simple carbon tool steel, the recognized reference standard. The relations for carbon steels between heat treatment, microstructure, and physical properties have been rather thoroughly studied and are summarized in another paper.[1]

To make the proposed correlation, the microstructure, hardness, density, magnetic properties, and thermal characteristics of a typical high speed steel as affected by various treatments were studied. The variety of properties investigated necessitated the co-operation of several other laboratories of the Bureau of Standards; H. S. Rawdon prepared the micrographs, E. L. Peffer made the density determinations, R. L. Sanford the magnetic tests, F. H. Tucker the chemical analyses, Miss H. G. Movius prepared the thermal curves, and several assistants aided in the work.

The previously published researches related to the present one are

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[1]See a paper "Thermal Changes Accompanying the Heating of Hardened Carbon Steels," by Scott and Movius which will appear in an early issue of TRANSACTIONS.

those of Edwards and Kikkawa,[2] Carpenter,[3] Yatsevich,[4] Mathews,[5] and Andrew and Green.[6]

Edwards and Kikkawa determined the effect of tempering temperature on the brinell hardness of two series of chrome-tungsten steels of constant carbon content, chromium being variable in one series and tungsten in the other. A constant hardening temperature of 1350 degrees Cent. was used with one exception, and the density changes of one representative composition were determined. This work represents the most important contribution to date to the study of the physical properties of high speed steels.

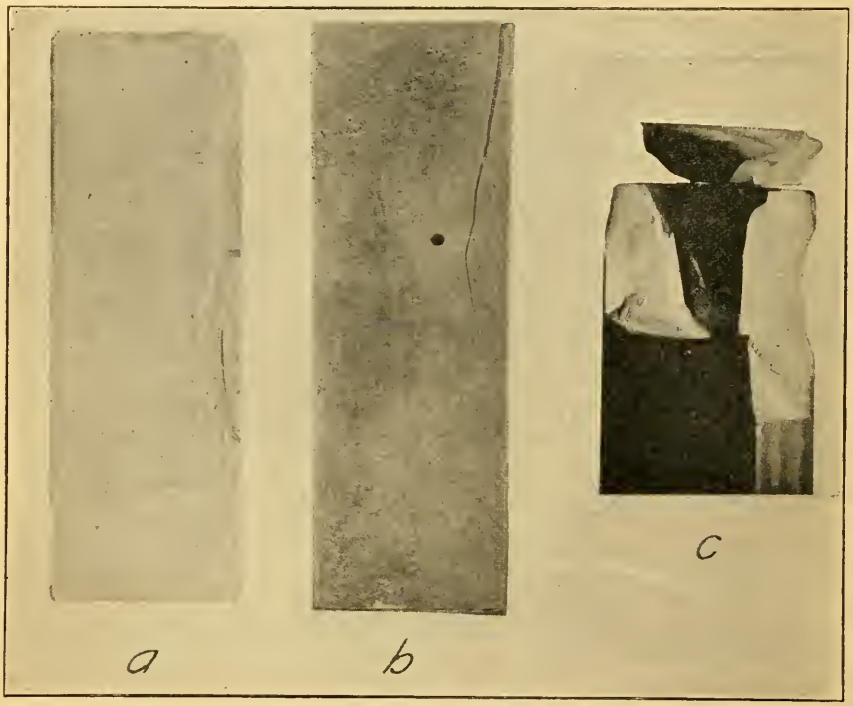


Fig. 1—Hardening cracks in high speed steel. Specimens of steel *B*, 1 x ⅝ x 3 inches, were hardened as follows: *a*, Quenched in oil from 1030 degrees Cent., surface of fracture parallel to 1 x 3-inch surface; *b*, cooled in air from 1050 degrees Cent., cracks perpendicular to 1 x 3-inch surface; *c*, quenched in oil from 1050 degrees Cent., fracture parallel and at 45 degrees to 1 x 3-inch surface.

Carpenter, Yatsevich, and Andrew and Green studied the critical ranges of high speed steels as affected by maximum temperature and rate of cooling.

Mathews summarized his wide experience with cutting and physical tests of high speed steel and reviewed developments since the classic experiments of Taylor and White.

These papers represent work on high speed steel of a wide variety of compositions and treatments, so that it is very difficult to establish any relation between the various properties studied. The present work is,

[2]Edwards and Kikkawa, Journal, Iron and Steel Institute, 92, page 6; 1915.
[3]Carpenter, Journal, Iron and Steel Institute, 67, page 433, 1905; 71, page 377; 1906.
[4]Yatsevich, Revue de Metallurgie, 15, page 65; 1918.
[5]Mathews, Proceedings, American Society for Testing Materials, 19, page 141; 1919.
[6]Andrew and Green, Journal, Iron and Steel Institute, 99, page 305; 1919.

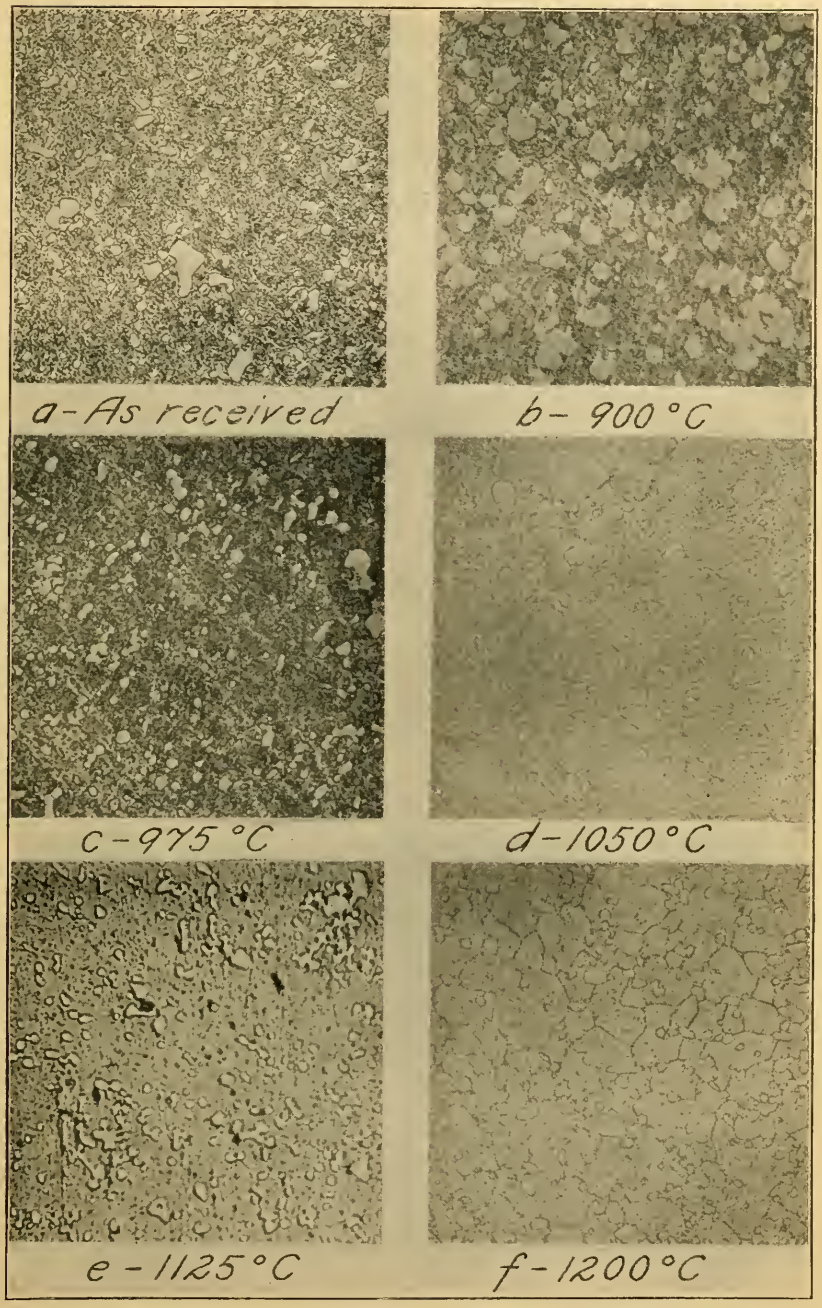


Fig. 2—Microstructure of specimens of steel *A* quenched from temperatures noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, Annealed; *b*, 900 degrees Cent.; *c*, 975 degrees Cent.; *d*, 1050 degrees Cent.; *e*, 1125 degrees Cent.; *f*, 1200 degrees Cent.

therefore, confined to one representative type of modern high speed steel.

For the purpose of this investigation tests were made on a standard type of high speed steel, chosen because it shows secondary hardening definitely. Unfortunately, sufficient material of one composition was not available, so that another composition was used also, this being purchased to duplicate the first as nearly as possible. As seen from the chemical composition given below, the two steels are very similar except in carbon content, which is low in the B steel for the brand used. As pointed out later, the lower carbon content, apparently, is responsible for a poor steel. The results of chemical analyses of high speed steels are as follows:

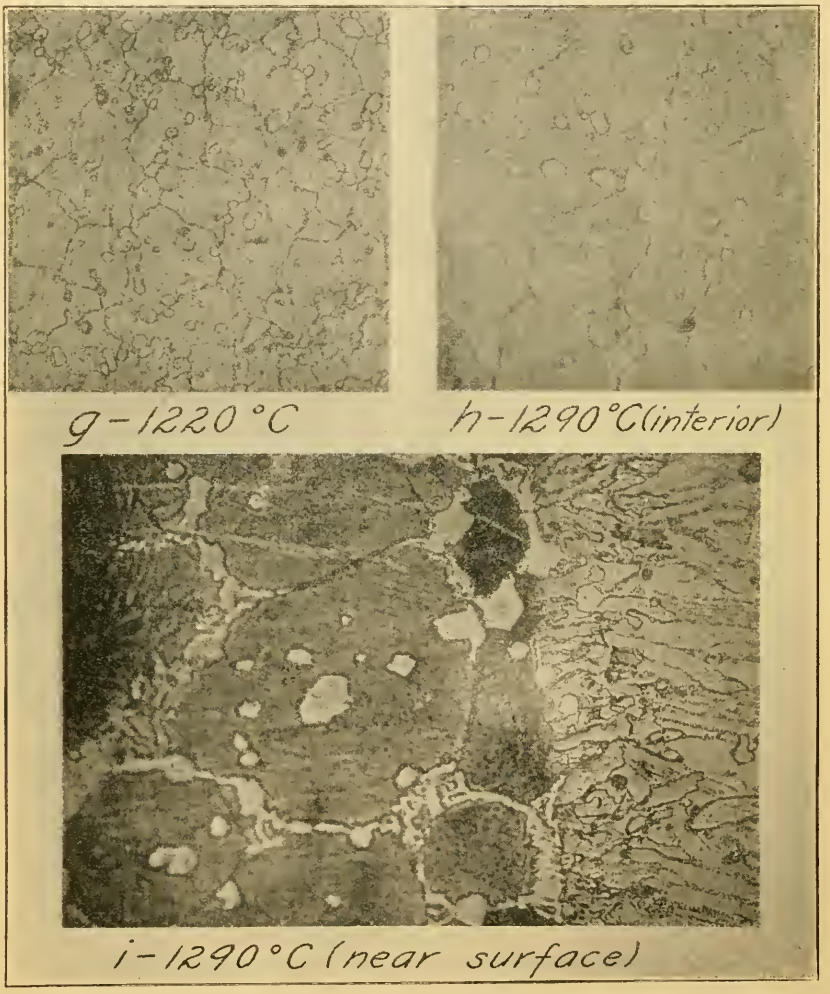


Fig. 3—Microstructure of specimens of steel A quenched from temperatures noted. Specimens x 500. Etched with 2 per cent nitric acid. *g*, 1220 degrees Cent.; *h*, 1290 degrees Cent., interior; *i*, 1290 degrees Cent., near surface.

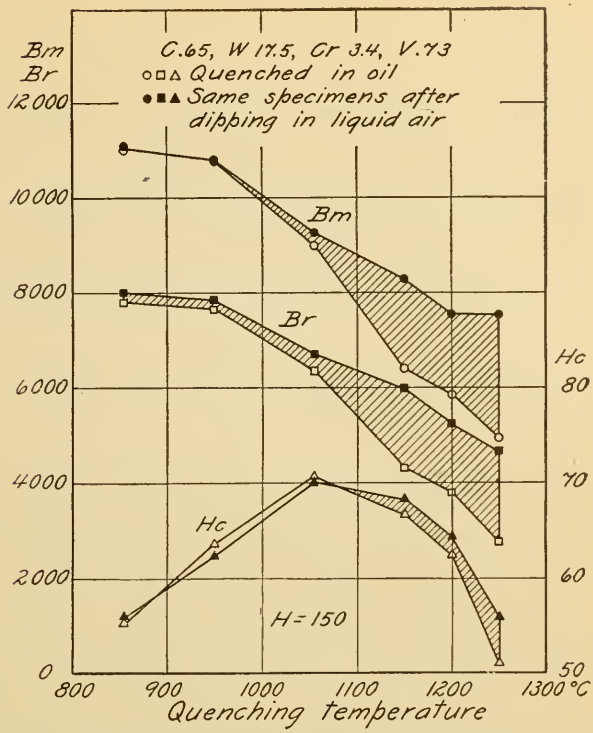


Fig. 4—Relation of quenching temperature and subsequent treatment in liquid air to maximum induction, residual induction, and coercive force of steel *B*.

Steel No.	Carbon Per cent	Manganese Per cent	Silicon Per cent	Tungsten Per cent	Chromium Per cent	Vanadium Per cent	Phosphorus Per cent	Sulphur Per cent
A.....	0.77	0.25	0.47	17.8	3.5	0.74	0.020	0.03
B.....	0.65	0.31	0.17	17.6	3.4	0.73	0.004	0.04

For hardening, the specimens were placed in an electrically heated alundum tube furnace in which charcoal or illuminating gas was burned to prevent excessive oxidation. The specimens were slowly brought up to temperature and held there 15 minutes before quenching. The quenching medium was a light mineral oil. Tempering consisted of heating for 15 minutes in an oil bath for temperatures up to 250 degrees Cent., in a nitrate bath up to 600 degrees Cent., and in a chloride bath for higher temperatures. The use of these baths assured a uniform temperature quickly reached. All high temperature measurements were made with platinum thermocouples.

The specimens were cut from a 1-inch square bar (steel A), and a 1 x ⅝-inch bar (steel B), both factory annealed. The magnetic test specimens were of 1 centimeter square cross section, the hardness specimens were of 1 x ¼-inch (steel A), and 1 x ⅝ inch (steel B) section, and the density specimens about 1 x 1 x ½-inch, as shown in Fig. 7, and about ½-inch face cubes, shown by Fig. 5. Specimens for micrographs were taken from the ends of the hardened magnetic test pieces.

In hardening, both steels usually cracked when quenched from the

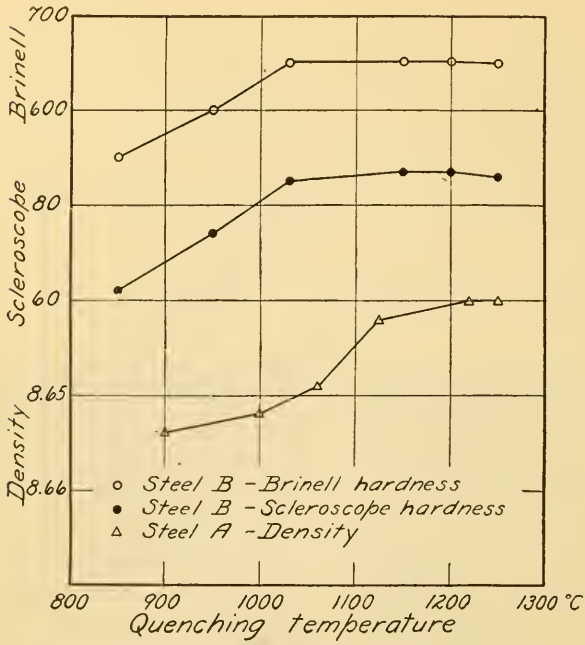


Fig. 5—Relation of quenching temperature to Brinell and scleroscope hardness of steel *B* and to density of steel *A*.

region of 1050 degrees Cent. The cracks followed the contour of the specimens, thus indicating that they were characteristic of the steel and not due to inclusions. The cracking was particularly severe in the case of the low carbon steel B, photographs of typical samples of which are shown in Fig. 1, a, b and c. This steel cracked also on cooling in air from 1050 degrees Cent. It was, however possible to obtain specimens on which the physical measurements could be satisfactorily made in spite of the cracks.

The density measurements were made by the usual method of weighing in air and in water, the specimens being dipped in alcohol prior to immersion in water to insure the absence of bubbles. The magnetic measurements were made in a long solenoid, corrections being made by the use of shearing curves. Other tests were made by the usual standard methods.

It has long been recognized that raising the quenching temperature increases the cutting efficiency of a high speed steel tool, so that the highest temperature short of fusion is the best. Observations were therefore made to determine the effect of quenching temperature on the properties under consideration to obtain evidence as to the nature of the constitutional changes.

The microstructure of steel *A* as quenched from several temperatures is shown in the micrographs of Figs. 2 and 3, the magnetic properties in Fig. 4, lower curves of shaded areas, and the density in Fig. 5. The effect of quenching temperature on the brinell and scleroscope hardness of steel *B* is also shown in Fig. 5.

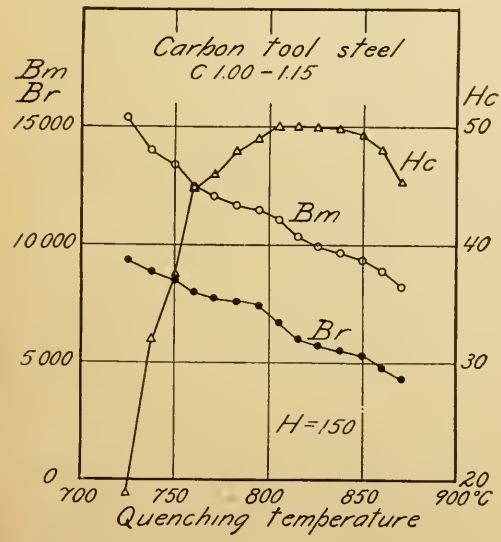
These data permit of a classification of the quenched specimens into two groups according to the nature of their physical characteristics. The

properties of the first group, quenched from temperatures up to about 1100 degrees Cent., vary in a manner distinct from those of the second group, quenched from above that temperature. Besides the change in slope of the curves, the physical properties of the two groups are affected differently on cooling below ordinary temperatures. Thus the magnetic properties of the specimens quenched from the high temperatures are markedly increased as shown by Fig. 4, upper curve of shaded area, by immersion in liquid air, while the specimens quenched from the low temperatures remain practically unchanged. This is indicative of a constitutional difference, other than a continuously changing one, between the specimens of the two groups and has an important bearing on the anomalies of high speed steel.

To distinguish between these two groups, specimens quenched from the lower temperature range will be referred to as given the low temperature treatment, and those from the upper range as given the high temperature treatment.

The microstructure of the samples given a low temperature quench is obscured by the excessive amount of free carbide imbedded in the apparently structureless matrix. The microstructure of the specimens of this series will be called martensite from their physical characteristics, but it must be recognized that this may be a misuse of the term, depending, of course, on its definition. The specimens quenched from the high temperature range show well defined grain boundaries in a structureless matrix containing little free carbide. This structure is typical of properly quenched high speed steel and will be called polyhedral.

The polyhedral structure, smaller volume change, constancy of hardness, and more rapid loss in magnetization with quenching temperature in this range are all suggestive of austenitization, though the polyhedral



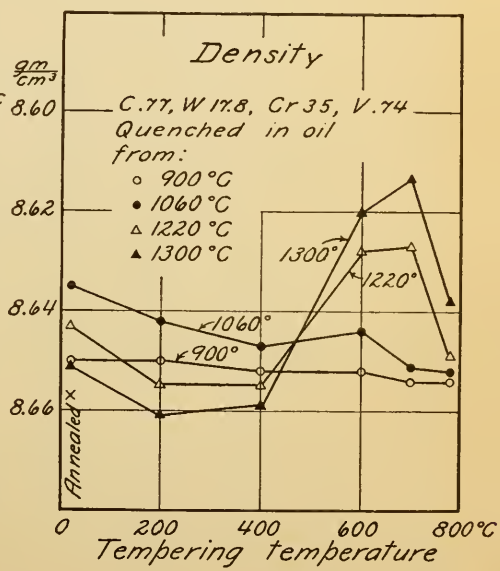
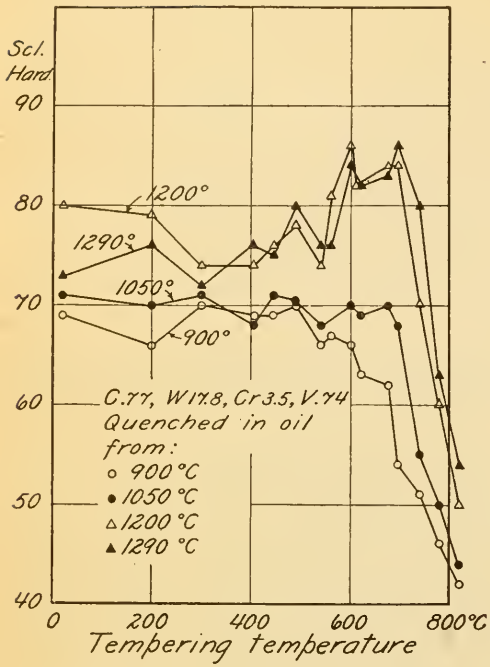


Fig. 6—(left) Relation of quenching temperature to coercive force, maximum induction, and residual reduction of carbon tool steel. (Gebert) Fig. 7—(right) Change in density of steel *A* with tempering temperature.



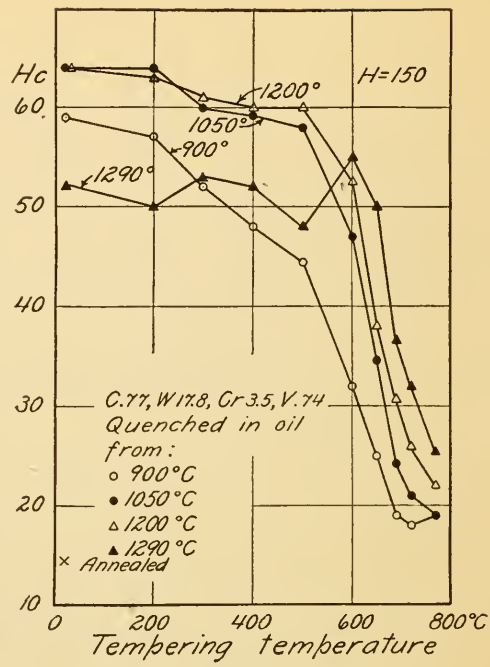


Fig. 8—(left) Change in scleroscope hardness of steel *A* with tempering temperature. Fig. 9—(right) Change in coercive force of steel *A* with tempering temperature.

structure is not necessarily proof of it. It is seen by extrapolation of the magnetic properties that zero magnetization, and hence complete austenitization, would be attained for a quenching of about 1450 degrees Cent. if this temperature could be reached without fusion. That partial austenitization has occurred on quenching from the high temperature range is shown, however, by the changes in physical properties on cooling below ordinary temperatures. This treatment, if carried to a low enough temperature, completes the A_3 transformation with a corresponding change in physical properties, direct evidence of previous austenitization. The effect on the magnetic properties of immersion in liquid air is shown in Fig. 4. The volume also increases on cooling below ordinary temperatures, a drop in density of 0.059 grams per cubic centimeter being observed when a specimen of steel *A* quenched from 1300 degrees Cent., was cooled to —45 degrees Cent. It must be concluded, therefore, that the specimens quenched from the high temperature range are constitutionally different from those given the low temperature treatment in that in the former case the steel is partially austenitic, but is not in the latter.

This characteristic of high speed steel may appear peculiar to it, but on reference to the work of Maurer[7] one will find that more or less partial austenitization is common to simple high carbon steel quenched from a high temperature, the degree depending, of course, on the carbon content and the temperature. This phenomenon is revealed by the change in density and in other physical properties on immersion of the steel in liquid air.

A further analogy between carbon and high speed steel may be seen

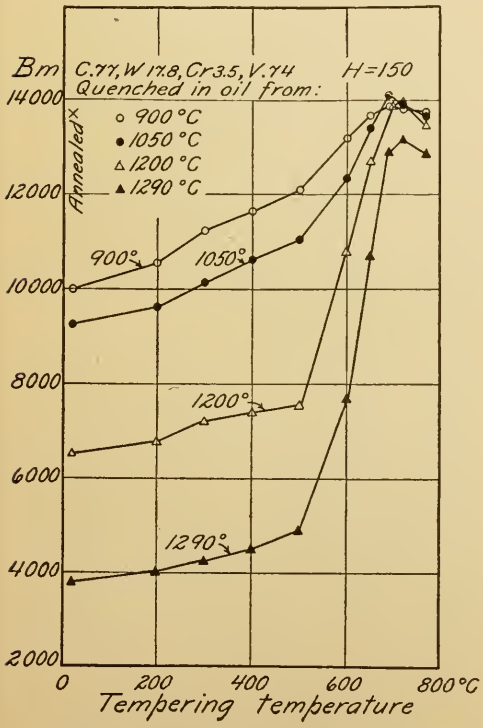
[7]Maurer, Revue de Metallurgie, 5, page 711; 1908.

by comparison of the effect of the quenching temperature on the magnetic properties of high speed steel, Fig. 4, with the effect of the same variable on those of a carbon steel, Fig. 6. The data for the carbon steel were taken from Gebert.[8] The similarity of these two figures is striking when the lack of any similarity in miscrostructure is considered.

The most interesting feature of the tempering of high speed steel is the socalled "secondary hardening," which is revealed as an increase in hardness over the original or a previous minimum of certain high speed steels given the high temperature treatment and tempered in the neighborhood of 600 degrees Cent. This, at first sight and in view of its absence in the usual carbon tool steels, is often considered a mysterious phenomenon. However, when the original condition of partial austenitization resulting from the high temperature treatment is considered, the phenomenon appears quite natural.

The effect of increasing the quenching temperature is to increase the amount of dissolved carbide which lowers Ar″ (Ar_{3-2} of martensitic steels, which is long and continuous for high alloy contents) progressively, until, for a quenching temperature of about 1100 degrees Cent., its end reaches room temperature. Any further increment of the quenching temperature—that is, quenching from the high temperature treatment range—will cause the end of Ar″ to fall below ordinary temperatures, with the result of partial austenitization already noted. This phenomenon is analogous to the lowering of Ar_3 in iron-nickel alloys by increasing the

[8]Gebert, Proceedings, American Society for Testing Materials, 19, Part II, page 117; 1919.



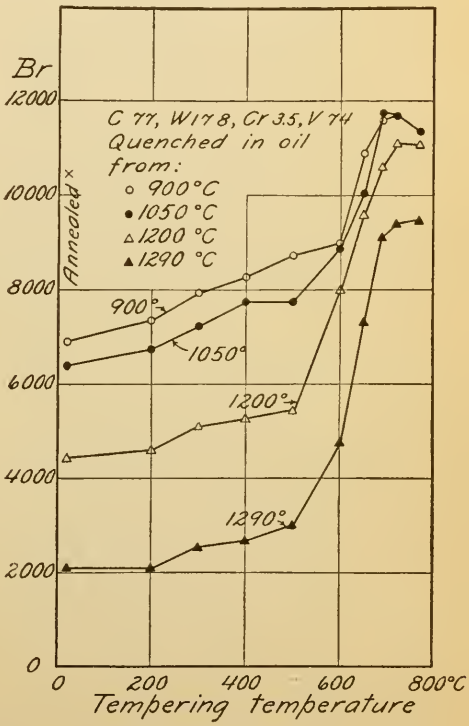


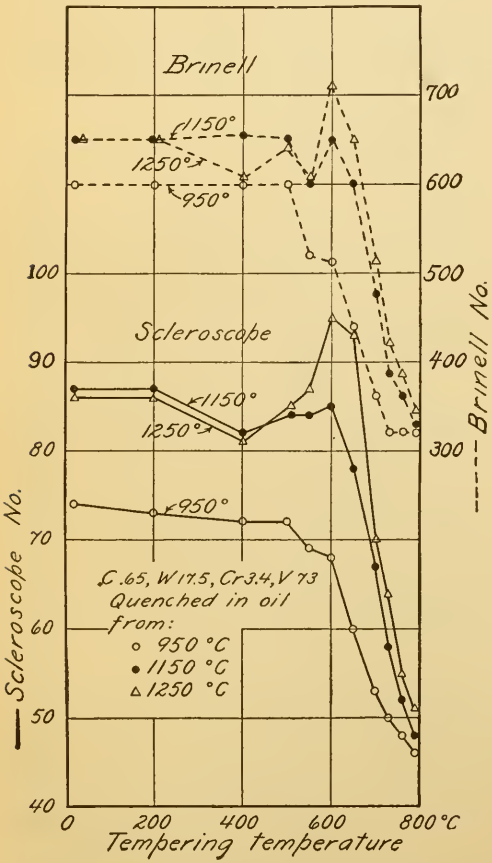
Fig. 10—(left) Change in maximum induction of steel *A* with tempering temperature. Fig. 11—(right) Change in residual induction of steel *A* with tempering temperature.

nickel content, the essential difference being that in the preceding case the composition of the matrix can be changed by tempering, but it can not be so changed in the latter.

From the foregoing analysis it is evident that on tempering the partially austenitic, and consequently somewhat softened steel, the dissolved carbide of the matrix will be gradually precipitated until a stage is reached at which Ar″ is no longer stable for the then existing temperature and composition of the matrix. Ar″ will then complete itself as in the case of the austenitic carbon steel discussed in another paper.[9] The consummation of Ar″ implies martensitization, and consequently an increase in hardness, which the physical property and microstructure data verify.

The effect of tempering temperature on the physical properties of steel *A* quenched from several temperatures is shown in Fig. 7, density; Fig. 8, scleroscope hardness; Fig. 9, coercive force; Fig. 10, maximum induction; and Fig. 11, residual induction. The reciprocals of the density values have been plotted to show more clearly their relation to the hardness values. In Fig. 12 are given brinell and scleroscope curves for steel *B*.

[9]See footnote 1.



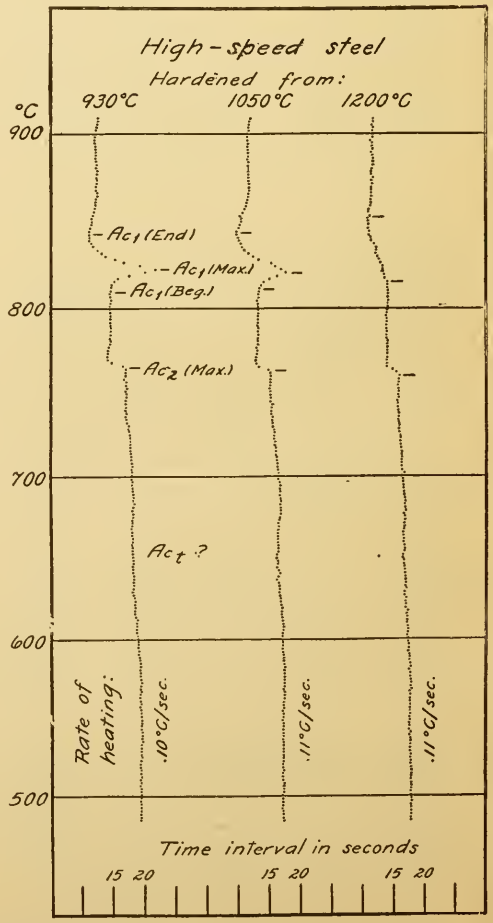


Fig. 12—(left) Change in Brinell and scleroscope hardness of steel *B* with tempering temperature.
Fig. 13—(right) Heating curves of quenched specimens, steel *A*.

The hardness curves, Figs. 8 and 12, show the phenomenon of secondary hardening only when the steel was quenched from the high temperature range, above 1100 degrees Cent., thereby confirming its relation to partial austenitization noted only in specimens quenched in the same temperature range. The curves representing the results of the low temperature treatment as similar to those of carbon steels with the exception that tempering occurs at a much higher temperature, thus shortening the temperature range over which troostite is stable, with the result that the change from martensite to sorbite, or complete softening, is quite abrupt. The density change is very small, indicating a slight solubility of the carbide in the low temperature treatment range.

Of chief interest is the tempering of specimens given the high temperature—that is, the most efficient—hardening treatment. The density curves, Fig. 7, show very markedly a peak between 600 and 700 degrees Cent., which is parallel to the hardness curves and corresponds to a large increase in volume. This is direct evidence of martensitization, and the magnetic properties offer further confirmation. The increase in maximum and residual induction, Figs. 10 and 11, normally indicative of softening, accompanies the rise in hardness in the secondary range.

Secondary hardening, as defined here, has been looked upon as a feature peculiar to high speed steel. The work of Maurer, however, shows that hypereutectoid carbon steels quenched from the neighborhood of A_{cem} exhibit the same phenomenon as revealed by density measurements, to a degree dependent on the amount of carbide retained in solution. The only difference between the high carbon and the high speed steel is that the peak comes at a much lower temperature in the former case, and the tempering below the peak is naturally more evident. The increase in intensity of the peak with an increasing degree of austenitization is evidence of a general relation between secondary hardening and partial austenitization.

The conclusions arrived at from an examination of the physical changes on tempering as related to the phenomenon of secondary hardening should be capable of verification by observation of the accompanying microstructural changes. Micrographs of specimens of steel *A* quenched from 900, 1050, 1200, and 1290 degrees Cent. are given in Figs. 14, 15, 16 and 17 respectively, as tempered at several temperatures. The first two figures show the structure resulting from a low temperature treatment and the second two from a high one.

Micrographs *a* and *b* of Figs. 14 and 15, low temperature treatment, show an immature martensitic pattern resulting from tempering at 300 and 400 degrees Cent. At 600 degrees Cent., the structure is apparently that of homogeneous troostite, and at 700 degrees Cent. the decomposition of troostite into sorbite is well advanced. It may be noted on referring to the relations between physical properties and miscrostructure of carbon steels[10] that the same general relations exist for the high speed steel quenched from the low temperature range.

The micrographs of specimens given the high temperature treatment, Figs. 16 and 17, show a rather astonishing phenomenon. Tempered at 200 and 400 degrees Cent., micrographs *a* and *b* a well developed, needle-like pattern, suggestive of martensite, is produced. When it is considered that the steel is still partially austenitic, the propriety of calling this constituent martensite is questionable. When tempered at 600 de-

[10]See footnote 1.

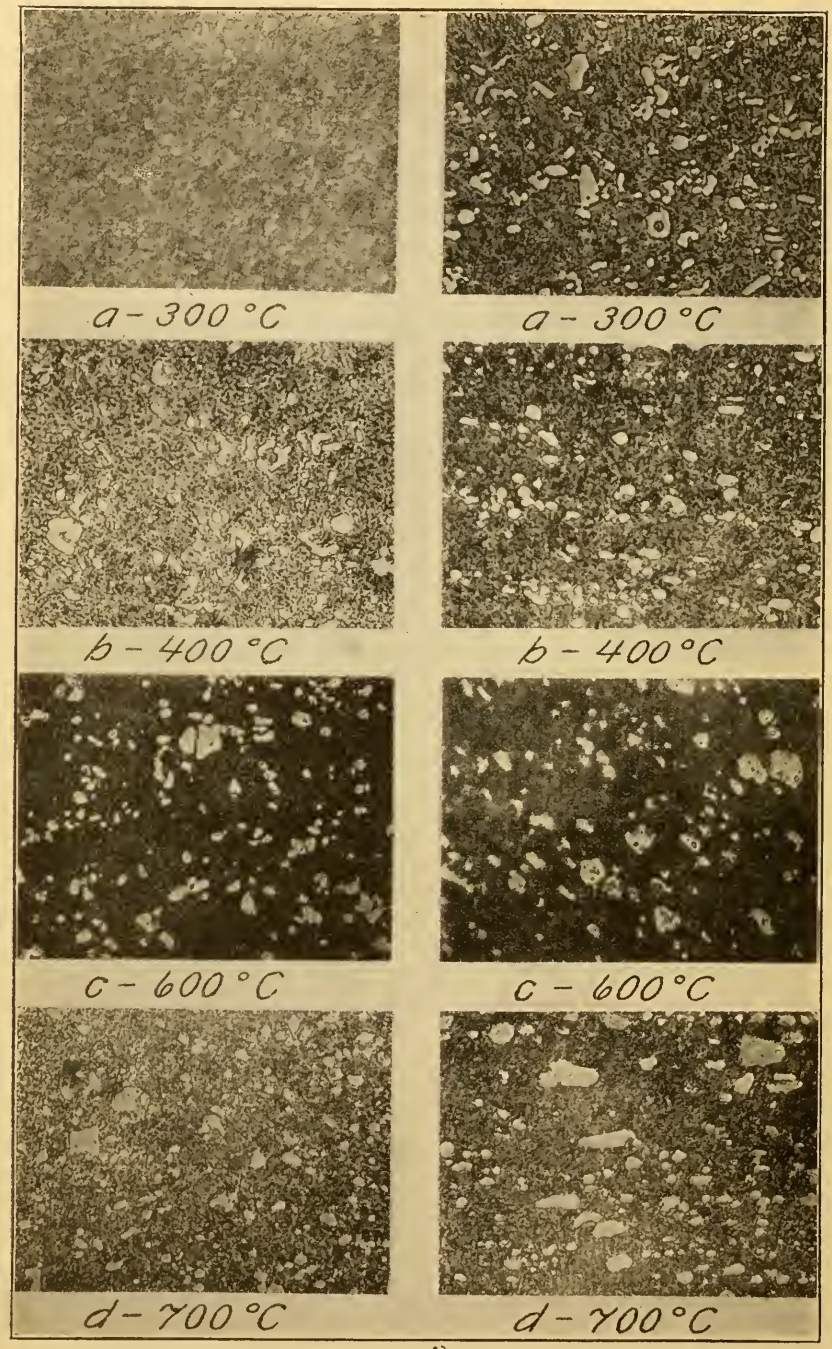


Fig. 14—(left) Microstructure of steel *A* quenched in oil from 900 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 300 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent. Fig. 15—(right) Microstructure of steel *A* quenched in oil from 1050 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 300 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent.

grees Cent., micrograph *c*, where secondary hardening first appears, a definite martensitic pattern quite similar to that of martensitic carbon tool steel is developed. For a tempering temperature of 700 degrees Cent., micrograph *d*, the structure is that of the first stages of troostite, of tempering, and for a temperature of 800 degrees Cent., Fig. *a*, it is that of sorbite, the structure here being practically identical for all quenching temperatures and similar to that of the annealed steel.

The microscopic evidence is positive and confirmatory of the physical, namely, that the constituent accompanying the appearance of secondary hardening is martensite. The nomenclature of the patterns developed at 200 and 400 degrees Cent., however, must await a more precise definition of the constituent martensite.

From the relations pointed out in a previous paper[10] between the heat evolution, Ac_t, observed on heating hardened carbon steels and the accompanying changes in physical properties and microstructure, it might be supposed that similar relations exist for the high speed steel. Heating curves were, therefore taken of steel *A*, Fig. 13, quenched from three temperatures. The inverse rate method was used, and the thermal characteristics noted on the curves are given in the table below. There is evidence of a slight heat evolution, Ac_t between 600 and 680 degrees Cent., but it is not sufficiently intense to allow of any positive conclusions. This is probably due to the rather limited solubility of the carbide in the matrix and the sluggishness of its precipitation, the rapid heating rate required by thermal analysis allowing insufficient time for its consummation. Note the loss in intensity of Ac_1 with increased quenching temperature. The transformation characteristics of steel *A* on heating following quenching are as follows:

Quenching temperature Degrees Cent.	Rate of heating Degrees Cent. per second	Ac_2 maximum Degrees Cent.	Ac_1 Beginning Degrees Cent.	Ac_1 Maximum Degrees Cent.	Ac_1 End Degrees Cent.
930	0.10	765	810	823	843
1050	0.11	763	811	821	844
1200	0.11	760	...	815	852

These curves are in substantial agreement with Carpenter's[11] observations from differential curves on a tungsten chromium high speed steel, with the exception that he does not recognize the transformation Ac_2, this due to the lack of its characteristic features in differential curves.

Inasmuch as the high grade high speed steels have much in common in spite of the wide range of compositions represented, it is permissible to generalize somewhat from the observations made on the familiar type of high speed steel used here. It must be remembered, however, that the degree of secondary hardening is a function of the carbon and chromium content and also, probably to a less degree, of the other alloying elements.

The rationale of the high temperature treatment becomes evident from an analysis of the physical characteristics. By defining red hardness as the resistance to softening by tempering, one may see from the hardness versus tempering-temperature curves that the red hardness increases slightly with quenching temperature. This is evidently one patent reason

[10]See footnote 1.
[11]See footnote 3.

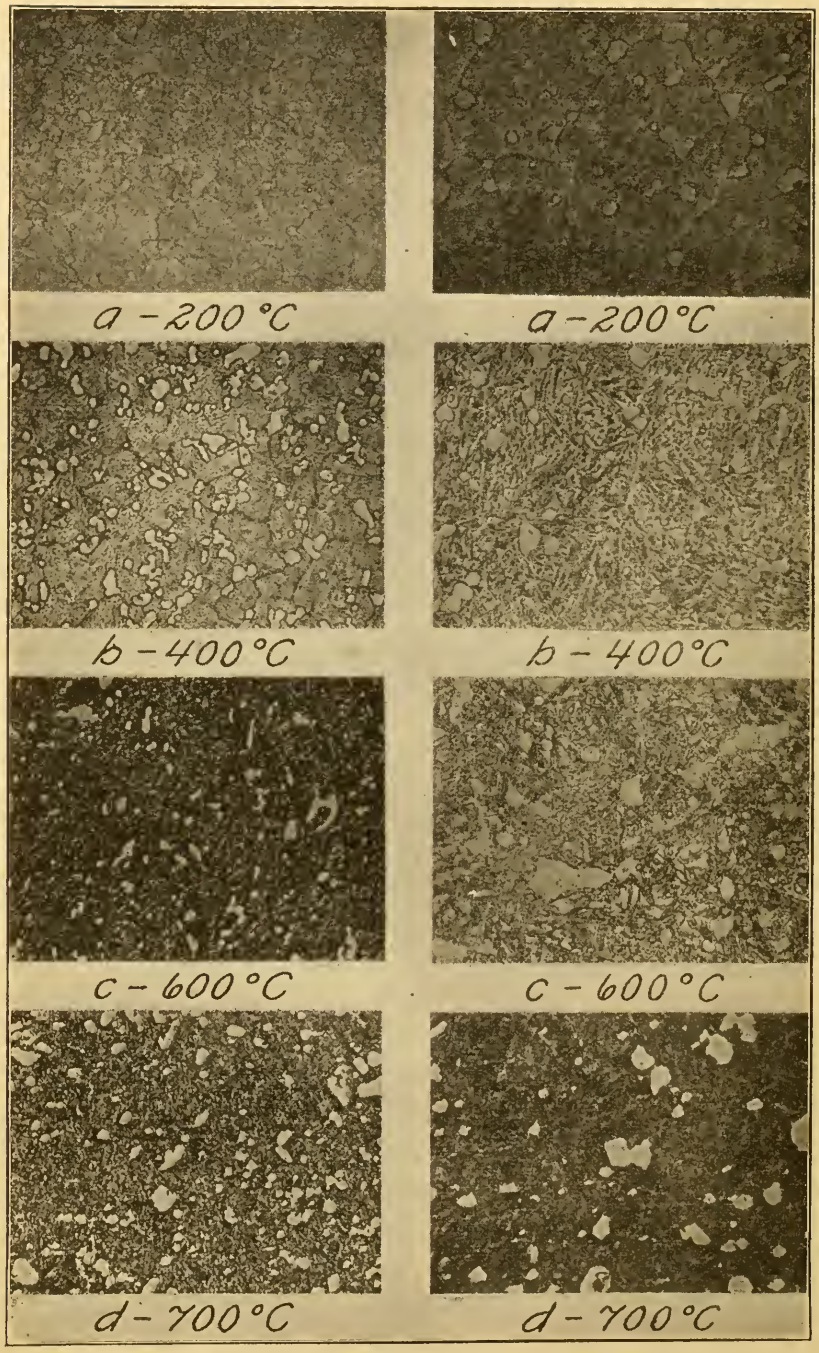


Fig. 16—(left) Microstructure of steel *A* quenched in oil from 1200 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 200 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent. Fig. 17—(right) Microstructure of steel *A* quenched in oil from 1290 degrees Cent. and tempered as noted. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, 200 degrees Cent.; *b*, 400 degrees Cent.; *c*, 600 degrees Cent.; *d*, 700 degrees Cent.

for a high quenching temperature. The initial hardness also increases with the quenching temperature, at least in the low temperature range, and this is a further highly desirable characteristic. With the increase in hardness there is a corresponding increase in volume and consequently in volume change on quenching, conditions which favor the formation of cracks. If, however, the steel be hardened from the high temperature range with partial austenitization, the density change is not increased, and the steel, even if not less hard, is less brittle, thus counteracting its tendency to crack and furnishing the most satisfactory combination of properties.

There has been much discussion as to the value of tempering for maximum hardness or secondary hardening. This is evidently largely a mat-

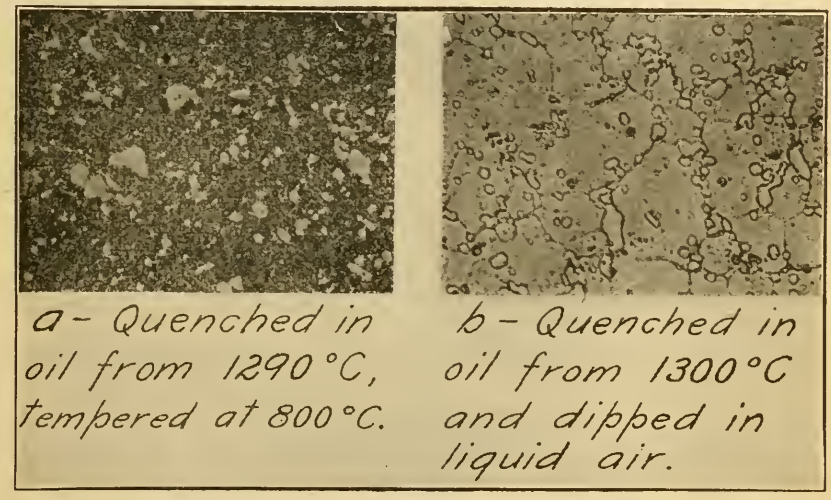


Fig. 18—Microstructure of steel *A*. Specimens x 500. Etched with 2 per cent alcoholic nitric acid. *a*, quenched in oil from 1290 degrees Cent. and tempered at 800 degrees Cent.; *b*, quenched in oil from 1300 degrees Cent. and dipped in liquid air.

ter of composition for a given treatment, as this factor determines the degree of secondary hardening possible. For a steel showing this phenomenon definitely, the increased hardness, if not accompanied by greater brittleness, which hardly occurs in this case, is certainly of value in a tool, no matter what its use. The increase in volume on tempering for secondary hardening deserves some consideration on selecting a treatment for a given tool. It is apparent that heating in service may change the dimensions of an untempered tool to a troublesome degree. Tempering for secondary hardening is, therefore, of general advantage, but it is certainly not of any value to temper at a lower temperature where these advantages do not accrue and where practically the same degree of effort is expended.

The comparatively long temperature range, about 100 degrees Cent., in which secondary hardening may be obtained suggests that a considerable constitutional difference between the product of the high and the low end of the range may exist, probably corresponding respectively to martensite and troostite. This being the case, it should be of interest to

determine whether the low or high temperatures giving the same degree of hardness will give the better cutting results.

The sharpness of the changes in the magnetic properties and in the density would indicate that these properties furnish a valuable test for determining without destruction whether or not a tool has been properly tempered. Of the hardness tests, the brinell is of little value on account of the very high degree of hardness involved. The scleroscope, however, if properly handled, is quite useful, although it is not as sensitive as the brinell to the advancement of the change from martensite to troostite. On the whole the physical properties determined for a hardened steel, while of course not furnishing a direct criterion of its cutting efficiency, do offer a valuable indication of the constitution of a given steel, and this is the principal value of most physical and mechanical tests.

Attention is called to the importance of fundamental research applied to high speed steel and the value of physical tests for this purpose.

The effect of heat treatment on the density, hardness, microstructure, magnetic properties, and thermal characteristics of a standard brand of high speed steel was determined. The interpretation of these data permits the following conclusions:

1. A high speed steel susceptible to secondary hardening is partially austenitic when quenched from a temperature high enough to produce this phenomenon.

2. The microstructure of steels hardened and tempered above 200 degrees Cent. is similar to that of carbon steels, although the same nomenclature in certain cases is not permissible.

3. The behavior of the physical properties of high speed steel on heat treatment is analogous to that of hypereutectoid carbon steel.

4. The following reasons are given for the use of the high heat treatment: (a) Increase of red hardness; (b) increase of initial hardness; and (c) reduction of brittleness.

5. High speed steel should preferably be tempered for secondary hardness.

SELECTION OF HIGH SPEED STEEL FOR TOOLS

By Henry Traphagen*

(A Paper Presented at the Philadelphia Convention)

A most perplexing problem confronting the tool manufacturer today is a steady supply of physically uniform high speed steel. Plenty of high speed steel on the market is chemically uniform, but it is a man's size job to cull out the physically defective material.

Without sound steel, the fabrication of high grade tools is impossible, for after all, no tool is any better or stronger than its weakest point. The most careful machine work, the best of the hardener's art, cannot save a tool from the scrap barrel if the steel is defective. It is true that careless or incompetent heat treatment will ruin the best of steel, but by no stretch of the imagination can we conceive of a tool giving satisfaction, if the raw material is physically unsound.

Judging from the mass of literature floating about the country, one would think that a steady supply of sound high speed steel is easily obtained, but after examining ton after ton from practically every important mill in the business, the writer is forced to the conclusion that consistently uniform high speed steel does not exist. The only recourse left to the careful conscientious manufacturer of tools, is to test every single bar of raw stock that is received.

Perhaps you will ask what do we mean by uniform high speed steel. We mean steel that is free from pipes, seams, cracks, segregated carbides, decarbonization and fiber—steel that will harden quickly and uniformly with a smooth velvety grain which is almost amorphous. That a steel should harden is not enough; the grain must be smooth and even, the steel must be tough as well as hard. An even grain will not compensate for a pipe down the center; hardness combined with a woody structure, means brittleness; and the finest grain in the world is absolutely nullified if that characteristic shiny crystalline ring of decarbonization is present. Will chemical analysis detect such defects? Will the scleroscope or Brinell machine reveal the presence of internal cracks or fiber? Show the author any test short of destruction by fracture, that will safeguard the consumer against such defects, and he will adopt such a test immediately and see that proper credit is promptly and fully given.

From the very beginning of its existence, the company for which the author is metallurgist, determined that nothing but physically sound steel should ever enter its tools. Every method of testing that could be suggested was tried and some of these experiences may be of interest.

For a long time every shipment was properly sampled and carefully analyzed. The author has in his office records covering over a thousand consecutive samples. In practically every instance the analysis was found to be satisfactory. Only two samples did not check up to the standard specifications. Such performance is a remarkable tribute to the efficiency of our steel works laboratories, but it is sad commentary on the insufficiency of chemical analysis, when it is stated that about 30 per cent of all steel received was rejected for physical reasons.

Hardness testing by the scleroscope and Brinell machine on both annealed and hardened samples showed nothing, for positively no connection was found between hardness and machine shop performance, barring of

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course, an occasional specimen that was underheated and very soft and which would easily bend.

It seemed that ordinary routine testing would not solve the problem, so scientific literature was ransacked in the hope that some simple test might be found that would detect internal defects. A wonderful assortment of physical test reports, photomicrographs, temperature curves, Brinell tests, critical point controversies, were gathered, only to lead to the conclusion that the steel industry was suffering from a bad attack of scientific indigestion.

Psychologists tell us that doing the obvious thing is the most difficult feat for humans to accomplish. If a thing is simple and obvious we generally overlook it. You know the old adage about judging the pudding by eating it. Why not test steel by hardening it? That is exactly what is being done today with every single bar of high speed steel that enters the author's plant. The procedure is as follows: As soon as steel enters the receiving room it is placed upon a special rack, and it does not leave that rack until it is either accepted or shipped back to the mill. A piece from each bar is hardened by preheating slowly and thoroughly at 1650 degrees Fahr., and then heating quickly in a furnace maintained at 2400 degrees Fahr., after which the piece is quenched in oil until cool. The hardened piece is then broken transversely and longitudinally and the fracture examined with a small low-power pocket lens.

If the piece breaks easily we are suspicious and look for either fiber or excessive carbides, and one or the other generally is found in brittle steel. If the steel is decarbonized the shiny crystalline ring is so apparent that it is found in a glance. Much of it is found. A pipe, no matter how small, may be uncertain in the transverse fracture, but the longitudinal break quickly shows it up. If the tungsten content is low, the structure generally is found to be coarse and crystalline when hardened at the high heat of 2400 degrees Fahr. Woody fibrous structures are very common, but always show up in the longitudinal fracture; in the transverse break, however, it is often masked. Rejections are never made on a single test. If the sample from one end of the bar is defective, one is cut from the other end, and if that fails the bar often is cut in two and the middle tested. In order to eliminate the possibility of incorrect heat treatment, at least two, often three men harden the samples on different days, without knowing where the sample comes from. It is possible for an error to creep in, in one hardening, but the average results of different men on different days where the defect appears again and again is positive proof that the steel is faulty. The test must be fair and no amount of retesting is spared if the slightest doubt exists. But in spite of such repeated and careful testing over 30 per cent of the steel goes back.

Is a clean, smooth uniform structure any index of a tool's value? To answer this question, dozens of drills were made up from what appeared to be excellent steel. These drills were tested not in the laboratory, but in a heavy-duty drill press. They were jammed through foot after foot of heat treated forgings, very little lubricant being used. The drills stood up. Then they were taken out of the presses, bounced on a concrete floor time and again to test for toughness, placed again in the drill press and the whole performance repeated. These tests coupled with many official competitive tests have proved many times the value of fracture tests in selecting high speed steel for drills and other tools.

Any criticism or suggestion to be of any value must be constructive. The object of this article is to place before the high speed industry, the necessity of rational physical testing. It is expensive and unpleasant to have to reject bar after bar of steel. The author gives assurance that the rejection of steel costs the consumer more than it does the manufacturer. If the fracture test should become more general it would not be long before experimental heat treating laboratories would be in every steel warehouse, and hardening would soon play as important a part in the testing of steel as chemical analysis now does.

In presenting this article, the author is not under the delusion that fracture testing is anything new or novel, but he does know that this simple exhaustive method of testing has not been given the consideration it deserves.

DISCUSSION OF MR. TRAPHAGEN'S PAPER

MR. D'ARCAMBAL: Have you ever run any tests on drills, drawing some to a temperature of 500 degrees Fahr. or thereabout, and also to 1100 degrees on tough steel?

MR. TRAPHAGEN: That is a case in which there are certain forms of very tough portions and toughness would have to be sacrificed for hardness. In that event we would use a full martensitic structure, but we know that the tool is liable to break, not from the hardness point, but from the action of wobbling or something of that sort.

MR. D'ARCAMBAL: We took a ¾-inch round bar of high speed steel and cut it in lengths of 7 inches. It was then turned down to 11/16 inches and the specimens quenched to 2300 degrees Fahr. in the open furnace. Half of these were drawn at 450 degrees and the other half to 1100 degrees. They were then put under the transverse machine, those drawn to 450 degrees broke at 4200 pounds while those drawn to 1100 degrees broke at 11,000 pounds at two and one-half times bending. I should think that would denote greater toughness on the 1100-degree draw. Those drawn to 450 degrees were brought up in oil and held 5 minutes; those at 1100 degrees were held about 10 minutes. I think that is one point that is not understood. I think drawing at 1100 degrees you get the greatest benefits by holding to 15 or 20 minutes.

MR. TRAPHAGEN: But has not its life started on the downward path?

MR. D'ARCAMBAL: All the tests were taken from the same bar of steel. It was regular high speed steel, 0.16 or 0.17 per cent carbon, 18.0 per cent tungsten, and 3.5 per cent chromium. It was etched and microscopical examinations made of it. This was not in the form of a drill.

MR. TRAPHAGEN: Did you break the whole thing wide open?

MR. D'ARCAMBAL: We supported it between V blocks and took the other V and broke it down. But on the cutter tests one of the factors is that of toughness; in tearing through the steel you have to have a pretty tough proposition. That is where the 1100 degree draw did two to four times the work that the 450 degree draw did.

MR. TRAPHAGEN: That may be, but we have found that our drills gave the best service when they were about 78 scleroscope, which is rather low. Somewhere around 85, which I think is also filed soft, does not stand up as well.

MR. D'ARCAMBAL: At a meeting a few minutes ago one man brought out that point. He was using the drills in tough metal, as good

as they could receive from the manufacturer, and it would not go through the tough steel. They drew them all to 1050 degrees Fahr. and got good results.

MR. TRAPHAGEN: We can do the same thing on the heat treated nickel-chrome forgings, but we have found somehow or other that then we have more trouble with the men snapping them off. They cut alright, however.

MR. D'ARCAMBAL: What temperature do you think the drill gets to in the usual running?

MR. TRAPHAGEN: I don't imagine it gets more than 400 or 500 degrees Fahr. at the maximum.

MR. D'ARCAMBAL: You said a drill would harden itself in service?

MR. TRAPHAGEN: It is a localized hardening, I think.

MR. STAGG: I can't help but rise in defense of the poor chemist and the hard working metallographist and the mere metallurgist. We know that material can be inspected fairly well by a simple test, and the usual tests that have been outlined, but in order to get a truer percentage of rejections, I am quite sure were it not for the activities of the poor chemist and the hard working metallographist and the mere metallurgists, the rejections instead of being 25 per cent would be perhaps somewhere nearer 75 per cent. One point in discussion; I think Mr. Traphagen mentioned the fact that he was going to not quite a martensitic structure and then later he mentioned the fact that he was drawing at 1100 degrees Fahr.

MR. TRAPHAGEN: The point is the matter of time. We leave it in there only about 30 seconds, just enough to start it going. You could easily get the martensitic structure if you leave it there long enough. We just start it going. One more point in that connection; I made the statement that the chemist and the laboratory are absoluely essential for the production of steel, but I am talking about the consumer of steel analyzing that stuff and applying the microscope to find out its suitability for his product. In other words, he must get his product practically made and then find out the condition of that steel as a whole, not as a part. Your point is well taken. A steelworker couldn't exist without a laboratory, but there are too many manufacturers spending a lot of money on equipment and chemists and fellows of that sort when they ought to have a good hardener. I am willing at any time to pay full tribute to what the metallurgists and chemists have done for the steel industry, but the trouble is that there is no proper backing up of them by the other fellows in the right way.

MR. D'ARCAMBAL: I am not a man of the steel mills, so I am going to stand up for the consumer. In the case of these cutter tests we ran, the No. 7 steel ran only 1.18 per cent vanadium and the fracture was beautiful and it did not show anywhere near the efficiency of the 1.75 per cent vanadium steel.

MR. TRAPHAGEN: In working with a standard product, did you take the pains to fracture that steel in two directions?

MR. D'ARCAMBAL: We didn't.

MR. TRAPHAGEN: Sometimes you will find a most marvelous change. Your transverse section will work beautifully and the longitudinal section will be altogether different.

MR. D'ARCAMBAL: I also believe that 90 per cent of the rejec-

tions in our laboratory are on physical tests, but every once in a while we get a steel with lower carbon and we don't find that out until we make the thing up, or a steel with lower tungsten, and it will give a nice fracture, but it will not give the efficiency.

MR. TRAPHAGEN: We have a laboratory, but we have found that as a rule a low tungsten steel will not stand up. When we get a tool and break it open and find something wrong with the fracture and after we have done that two or three times to be satisfied that the heat treater is off the job, then we start with the microscopes and work backwards. But we do not waste time in useless routine analysis or taking pictures when we can tell immediately by making a fracture. In addition to making a fracture on the lower steels, I grab half a dozen drills and smash them up. Every once in a while we will take a drill outside and try it for 15 or 20 minutes. Now, taking all those tests together and using science to ferret out some of the difficulties, I think we have a good check up.

MR. D'ARCAMBAL: I agree with you that the fracture test has not been developed to the limit of its possibilities.

MR. TRAPHAGEN: It is the test of the steel man almost altogether. He wants to try it on everything.

MR. D'ARCAMBAL: When you come to carbon tool steel, you get a carbon tool steel that is annealed from the mill and it will show you a crystalline structure, but your fracture will not show you that.

MR. TRAPHAGEN: When you harden that piece of steel, break it open transversely where you think it is hardened down so far you cannot break it any further. I have broken 17 bars of one of the best known steels made just recently, and I found one good one out of the 17, and yet they were beautiful on the surface. But they only were good down a little distance. They run from temperatures of 1425 up to 1700 degrees Fahr. Then I increased the time in the lathe from 2 minutes to 10 and combined the long time and the long immersion and couldn't get any change.

News of the Chapters

NEW CHAPTER ESTABLISHED IN WORCESTER

The organization meeting of the Worcester chapter of the American Society for Steel Treating was held on April 27 with about 65 men in attendance. The principal speakers of the evening were: John F. Tinsley, vice president and general manager of the Crompton & Knowles Loom Works who gave a very interesting talk on the "Advantages of Metallurgical Study"; and Alvin T. Simonds, president of the Simonds Mfg. Co., spoke with reference to the advantages of close co-operation between producers and fabricators of steel.

Other speakers were: R. C. Helm, metallurgist of the American Steel & Wire Co.; Leslie C. Heath of the Simonds Mfg. Co.; and John

VICTOR HILLMAN
Elected Chairman of New Worcester Chapter

J. E. ROGERS
Elected Secretary-Treasurer of New Worcester Chapter

H. C. KNERR
Elected Vice Chairman of Philadelphia Chapter

ALEXIS CASWELL
Re-elected Secretary-Treasurer of North West Chapter

C. Spence, superintendent of the Norton Co., machine division, who gave their views on the advantages of the Society.

Election of officers resulted in the following selection: Chairman, Victor E. Hillman, metallurgist of the Crompton & Knowles Loom Works, Worcester, Mass.; secretary-treasurer, J. E. Rogers, secretary, A. Hankey & Sons Co., Rochdale, Mass. Members of executive committee: Thure Larson, mechanical engineer, the Norton Co., Worcester, Mass.; Paul A. Porter, Worcester, Mass.; Chester M. Inman, Pratt & Inman, Worcester, Mass.

Chairman Hillman stated the aims and purposes of the Worcester chapter as follows:

"Tonight marks the inception of the Worcester chapter of the American Society for Steel Treating. The time is come when Worcester and her environs feel that they can support an offspring of the parent body. The National Organization, of which we become a part, resulted from the fusion of two independent societies, each of which were disseminating knowledge pertaining to the metallurgy of iron and steel. The result was that a powerful society sprang into existence, with headquarters in Cleveland, and a membership of 2959.

"America's foremost metallurgists have affiliated themselves with the organization. Fifty-four steel companies are listed as sustaining members. The proceedings of the body are recorded in a monthly publication known as Transactions. Those of you who are familiar with the journal will admit that it is an arsenal of knowledge and that it contains a wealth of ideas.

"Sir Robert A. Hatfield, an English metallurgist, and the inventor of manganese steel, is an honorary member of the national body. As you have probably read in the daily press, he will receive the John Fritz medal in London, June 29. The presentation is of particular interest to Worcester people, because Dr. Ira N. Hollis, President of the Worcester Polytechnic Institute will convey America's greetings.

"Twenty-eight chapters are located in various industrial centers of the country. Each is glowing with youth, vigor, and vitality, and our birth tonight will place a formidable rival in their midst. The purpose of creating a local chapter is to bring the executive, the laboratory technician, the foreman, and the mill operator into closer relationship. In brief, we propose to fuse apprenticeship, practical experience, and technical knowledge into one homogeneous mass. Papers will be presented from time to time, after which a general discussion dealing with various phases of the subject will be in order.

"Our chapter will also feature what is known as a 'question box'; that is, every one who attends the meeting of the society is privileged to submit his questions in writing to the presiding officer. The chairman will make an effort to have them answered. For instance, you may be experiencing trouble in machining a certain grade of steel. You are asking a remedy for overcoming the difficulty. There will always be men in attendance who are qualified to suggest ways and means for obtaining relief. Or again, you may be sustaining enormous losses due to the fact that you are violating certain fundamental metallurgical laws. If your trouble is brought up for open discussion, I feel confident that everyone will contribute his share of experience toward the solution of your problem.

"The chapter has a message to extend to all those who are inter-

ested in steel and its heat treatment. If we avail ourselves of the opportunity to mingle with one another, we will absorb and impart ideas in accordance with the adage, 'a fair exchange is no robbery'. If we are to pass through the channels of progress, we must rub elbows with one another. One man's experience alone is not worth a continental, and any one who professes to be self-satisfied with his knowledge, is either a fool or a knave.

"Our nation hold a pre-eminent position as being the largest iron and steel producing country in the world but unfortunately we have not contributed our share to the advancement of the art. Professor Sauveur of Harvard sounded the keynote of our apathy, in Philadelphia last September when he viewed the basic metallurgical inventions in retrospect.

"Even though we make more pig iron, coke, open-hearth steel, wrought iron, electric steel, ferroalloys, and malleable iron than any other country in the world, the basic inventions thereof sprang from foreign shores. The blast furnace was neither developed nor invented in the United States. Coke owes its origin to an Englishman by the name of Abraham Darby. The utilization of blast furnace gases is credited to Aubertot of France: Open-hearth and bessemer steel to Emile Martin and Sir Henry Bessemer of England; electric steel to the French metallurgist Heroult; wrought iron to Henry Cort of England, and malleable iron to the French chemist Reaumur.

"But notwithstanding, American genius is awake to the situation, and she found a niche in the metallurgical hall of fame when Taylor and White of the Bethlehem Steel Co. announced their discovery of high speed steel. I have cited these illustrations in passing, merely to stimulate interest in that fascinating subject, iron and steel".

The second meeting of the Worcester chapter was held on May 19 in the rooms of the New England Metal Trades Association, and was addressed by S. C. Spalding, metallurgist of Halcomb Steel Co., who delivered a very interesting and instructive paper. Eighty-five were in attendance.

BRIDGEPORT CHAPTER

The annual meeting of the Bridgeport chapter was held in the Upper Gymnasium, of the Y. M. C. A. building, on May 10. The meeting was called to order at 7:50 P. M. by Chairman Rodney, when the evening program was carried out. A lecture was given by G. A. Richardson, of the Midvale Steel and Ordnance Co., entitled "The Process of Steel Manufacture" and was illustrated by moving pictures. Communication of "Congratulations" from the national secretary, W. H. Eiseman, was read. An enjoyable evening was spent by the 67 members present.

The following officers for the ensuing year were elected: Chairman, Harold T. Dow, superintendent, Spring Perch Co., Stratford, Conn.; vice chairman, Herold Fish, treasurer, Ready Tool Co., Bridgeport, Conn.; secretary-treasurer, C. F. Schmelz, superintendent, Curtis & Curtis, Bridgeport.

Executive Committee: A. G. Baldwin, International Silver Co.; J. E. Cooper, Columbia Nut & Bolt Co.; E. B. Crocker, mechanical engineer, Manning, Maxwell & Moore, Inc.; H. T. Leavenworth, manager Bridgeport Testing Lab.; W. S. Lynne, factory manager Bridgeport Metal Goods Mfg. Co.; J. S. Marran, chief inspector, Remington Typewriter Co.

LLOYD K. MARSHALL
Elected Chairman of Rochester Chapter

ARTHUR W. F. GREEN
Elected Chairman of Philadelphia Chapter

JOHN E. HALBING
Re-elected Chairman of Lehigh Valley Chapter

ALBERT P. SPOONER
Re-elected Secretary-Treasurer of Lehigh Valley Chapter

SPRINGFIELD CHAPTER

The May meeting of the Springfield chapter was held in the Chamber of Commerce building, on May 20. S. C. Spaulding, metallurgist of the Halcomb Steel Co., Syracuse, N. Y., gave a very interesting talk on the "Cause of Failure of Steel". The subject was handled in a thoroughly practical manner and dealt with the causes of many perplexing failures

resulting from improper treatment or handling of the steel in the shop.

The following officers have been elected for 1921-22: Chairman, R. J. Allen, metallurgist, Rolls-Royce Co. of America; vice chairman, E. A. Sanford, metallurgist, Hendree Mfg. Co.; secretary-treasurer, E. L. Woods, industrial gas engineer, Springfield Gas Light Co.

SCHENECTADY CHAPTER

The Schenectady chapter leads as far as securing newspaper publicity is concerned, and sets an example toward which the other chapters might well aim. The following report is taken from the Union Star of May 6:

"Nearly 100 members and guests of the Schenectady chapter of the American Society for Steel Treating were present last evening at the Civil Engineering building, Union College, and heard Lieut. Col. A. E. White, national president of the society and director of engineering research at Michigan University, deliver a lecture on "Alloy Steel—Its Rise and Secrets". Lieut. Col. White is a national authority on alloy steel and has investigated the subject very thoroughly, consequently his paper was of much interest to those in attendance.

"Through the courtesy of some of the members of the Union College Radio Club the much-talked of "Baby Carriage" delivered music via wireless, and the concert was greatly enjoyed and exceedingly interesting.

"A guessing contest was also a feature of the evening entertainment and provided considerable amusement. If the winner did not peep—he's a good guesser.

"Officers were elected as follows: Chairman, Carl L. Ipsen, designing engineering, General Electric Co.; vice chairman, E. J. Edwards, engineer of tests, American Locomotive Co.; secretary-treasurer, B. T. Perry, chief chemist, American Locomotive Co.

"Executive Committee: F. P. McKibben, professor of civil engineering, Union College; E. F. Collins, General Electric Co.; R. Topham, General Electric Co.; B. H. Magill, American Locomotive Co. Their term of office is from May, 1921, to May, 1922. Plans are being completed for the June meeting and an interesting program is promised."

ROCHESTER CHAPTER

The annual meeting of the Rochester chapter was held in the Eastman Building, University of Rochester, on Thursday, May 19. Lieut. Col. A. E. White, national president of the Society, presented a paper on the subject "Alloy Steel—Its Rise and Secrets". Lt. Col. White's paper was very favorably received and the discussion following its presentation was participated in by a large number of those in attendance. The national secretary, W. H. Eiseman, spoke of the advances the society had made during the past year and gave information about the coming convention at Indianapolis.

The following officers were elected for the chapter for the year 1921-1922: Chairman, Lloyd K. Marshall, North East Electric Co.; vice chairman, J. J. Desmond, North East Electric Co.; secretary-treasurer, R. C. Schwarz, 421 Arnett boulevard; member-at-large, Wm. H. Chappell, General Railway Signal Co.; member-at-large, W. W. Phillips, Colonial Steel Co.

PITTSBURGH CHAPTER

The Pittsburgh chapter held its regular monthly meeting at the Chatham Hotel on Tuesday, May 17. Due to the illness of the national president, who was to deliver the principal address of the evening, W. S. Bidle, national treasurer, and W. H. Eisenman, national secretary, substituted. The meeting was well attended and although considerable disappointment was experienced because of the inability of Lt. Col. White to be present, those in attendance had a very enjoyable evening.

The officers elected for the coming year were as follows: Chairman, Dr. C. M. Johnson, director research department, Park Works, Crucible Steel Co. of America; vice chairman, Dr. N. B. Hoffman, Colonial Steel Co.; secretary-treasurer, D. W. McDowell, Jones & Laughlin Steel Co.

For Board of Directors: Prof. Frederick Crabtree, professor of metallurgy, Carnegie Institute of Technology; Prof. S. L. Goodale, professor of metallurgy, University of Pittsburgh; T. D. Lynch, Westinghouse Electric & Mfg. Co.; F. C. Eaton, Pittsburgh Steel Wire Co., Monaca, Pa.; W. B. Crowe, Homestead Steel Works, Munhall, Pa.; Frank Garratt, Latrobe Steel Co., Latrobe, Pa.

CHARLESTON CHAPTER

The regular monthly meeting of the Charleston chapter was held in the assembly room of the Charleston Y. M. C. A. Tuesday evening, May 17. After disposal of the usual business, the annual election of officers for the ensuing year was held, resulting as follows: Chairman, W. J. Priestly, Quarters "B", Armour Park, South Charleston, W. Va.; vice chairman, H. Schagrin, 6 White Ave., S. Charleston, W. Va.; secretary-treasurer, W. H. White, Box 296, S. Charleston, W. Va.

Following the brief address of the newly elected chairman, an interesting and lively discussion of the subject "Flakes", their causes and effects, arose. The main feature of the evening's program consisted of an illustrated lecture by G. A. Richardson, Midvale Steel & Ordnance Co., in which the manufacture of steel from the mining of the iron ore to the shipment of the finished steel products was shown.

PROVIDENCE CHAPTER

The May meeting of the Rhode Island chapter was held in the rooms of the Providence Engineering Society on May 25th. Dr. C. M. Johnson, director of research, Park Works, Crucible Steel Co. of America, spoke on "Resistal Steels", which was illustrated, and proved to be very interesting and enlightening. Quite a large attendance was present, and the discussion of various heat treating problems and Mr. Johnson's paper contributed to make it a very profitable evening.

MILWAUKEE CHAPTER

The May meeting of the Milwaukee chapter was held on May 9, and was addressed by Prof. H. F. Moore, of the University of Illinois, on the "Fatigue of Metals". Over 100 were in attendance. The meeting was held jointly with the Milwaukee section of the American Chemical Society. The paper by Prof. Moore was illustrated by moving pictures, and was extremely interesting.

The second meeting for May was held on the 25th when Lt. Col. A. E. White, national president, paid his official visit to the chapter,

RALPH C. SCHWARZ
Re-elected Secretary-Treasurer of Rochester Chapter

C. B. SWANDER
Re-elected Secretary-Treasurer of St. Louis Chapter

D. W. McDOWELL
Re-elected Secretary-Treasurer of Pittsburgh Chapter

ARTHUR COLLINS
Re-elected Secretary-Treasurer of Philadelphia Chapter

and gave a very interesting paper. This meeting was also a business meeting, for the annual election of officers. E. Williams, chairman of the nominating committee, submitted a report of that committee.

PHILADELPHIA CHAPTER

The Philadelphia chapter had a very interesting meeting on April 29 in the auditorium of the Engineers' Club, when over 100 attended to hear Norman Einwechter of Philadelphia present a paper on the subject of "Normalizing Tool Steel and Preparing Same for the Steel Treater". The discussion was very lively and instructive and was participated in by Mr. Nelson, of Henry Disston Sons Co., who has recently arrived in this country, having been associated with the steel interests in Sheffield for a number of years. Mr. Brooks, of the Bethlehem Shipbuilding Corp., and Mr. Dawson, of Philadelphia Navy Yard, presented short talks on "Fundamentals of Heat Treating".

Interest is reaching a very high stage of development with reference to the institution of classes of metallurgy, metallography and heat treating in the Philadelphia schools having evening classes, and the idea at the present time is to have two classes each week for 30 weeks, each class to consist of two hours per night, or a total of 120 hours, including practical work and demonstration. The charge for this course will be approximately $30.00 and will be most complete and ably taught.

ST. LOUIS CHAPTER

The St. Louis chapter held its annual meeting on May 12 at the Planters Hotel with over 75 in attendance to hear Prof. H. F. Moore talk on the "Fatigue of Metals". The chapter enjoyed Prof. Moore's paper very much.

The election of officers resulted in the selection of the following men: Chairman, J. N. Maher, superintendent of the St. Louis Frog & Switch Co.; vice chairman, Chas. G. Kruckemeyer, St. Louis Screw Co.; secretary-treasurer, C. B. Swander, metallurgist, of Wagner Electric Mfg. Co.

BUFFALO CHAPTER

The April meeting of the Buffalo chapter was held on April 25, at which time the following officers were elected for the coming year: Chairman, W. H. Blocksidge, J. H. Williams Co.; vice chairman, W. H. Reiger, Sizer Forge Co.; secretary-treasurer, Hans Buerk, Buerk Tool Works. Two members of executive committee: John Miller, Pierce Arrow Motor Car Co.; C. E. McQuigg, Electro-Metallurgical Corp.

TRI-CITY CHAPTER

On May 11, the Tri-City chapter held its meeting at the Davenport Chamber of Commerce, and was addressed by Prof. H. F. Moore, of the University of Illinois, on the subject of "Fatigue of Metals". About 80 were in attendance and enjoyed a very excellent meeting.

The new officers for the Tri-City chapter as as follows: Chairman, Mr. A. H. Putnam, P. O. Box 653, Davenport, Iowa; vice chairman, J. F. Lardner, 723 20th St., Rock Island, Ill.; secretary-treasurer, C H. Lage, Linograph Co., Davenport, Iowa.

Executive committee: The three officers of the chapter and L. S. Rasmussen, Linograph Co., Davenport, Iowa; Harold Brown, Reynolds Engineering Co., Moline, Ill.

WASHINGTON CHAPTER

The May meeting of the Washington chapter was held in the ballroom of the Harrington Hotel, E Street, on Thursday, May 19. The subject

for discussion was the heat treatment of heavy forgings, and papers were delivered by Lawford H. Fry, superintendent of product, Standard Steel Works, Burnham, Pa., on "Theory and Practice in Quenching Large Locomotive Forgings", and also by Paul E. McKinney, metallurgist, United States Naval Gun Factory, Washington, D. C., on "Heat Treatment of Ordnance Forgings". Since both speakers are actively engaged in the heat treatment of steel, the papers dealt with practical metallurgical problems involved in the treatment of such work, more especially the influence of mass and temperature on the quality of the finished product. The meeting was very well attended and proved to be one of the best held by the chapter.

LEHIGH VALLEY CHAPTER

The Lehigh Valley chapter had a very successful meeting at the Public Library in Easton, when 150 were in attendance. The speaker of the evening was W. R. Shimer, sales metallurgist, Bethlehem Steel Co., Bethlehem, Pa., whose subject was "Manufacture of Steel".

The following officers for the year 1921-1922 were elected: Chairman; J. E. Halbing, Ingersoll-Rand Co.; secretary-treasurer, A. P. Spooner, Bethlehem Steel Co.

Executive Committee: H. Brainard, Ingersoll-Rand Co., Phillipsburgh, N. J.; R. Christ, Bethlehem Steel Co., Bethlehem, Pa.; W. R. Shimer, Bethlehem Steel Co.; G C. Lilly, 606 North Market St., Bethlehem, Pa.; F. Martin, Ingersoll-Rand Co., Phillipsburgh, N. J.; A. Hummel, William Wharton Jr. Co., Easton, Pa.; F. Ebner, 1922 Freemans Ave., Easton, Pa.; W. Laury, Bethlehem Steel Co., Bethlehem, Pa.; L. Larkin, M. E. Lehigh University, Bethlehem, Pa.

NEW YORK CHAPTER

The New York chapter held its May meeting at the Machinery Club, Hudson Terminal Building, 50 Church St., on Monday evening, May 18. S. P. Rockwell, metallurgist of the Whitney Mfg. Co., Hartford, Conn., presented a lecture on "Hardness Testing", which was illustrated by stereoptican views. Mr. Rockwell discussed and compared various methods of determining hardness of metals, and in particular the Rockwell hardness tester, invented by the speaker. About 75 members were present, bringing with them specimens of materials for testing. A very lively and interesting discussion and demonstration followed the paper.

The new officers of the New York chapter are as follows: Chairman, George L. Norris, Vanadium Corp. of Amer., New York City; chairman of entertainment committee, A. E. Barker, Firth-Sterling Steel Co.; secretary-treasurer, T. N. Holden Jr., chemist, E. W. Bliss Co., Brooklyn.

CINCINNATI CHAPTER

The regular meeting of the Cincinnati chapter was held on Friday, May 20, at the Ohio Mechanic Institute, Cincinnati. The paper of the evening was presented by C. P. Richter, of the Central Steel Co., Massillon, Ohio, who selected for his subject "Alloy Steel and Common Sense". The speaker handled the subject in a very interesting and entertaining manner, and the 60 members in attendance had a very enjoyable evening.

The election of officers was held at this meeting and resulted in the following selections: Chairman, R. M. Taylor, American Tool Works Co.; vice chairman, A. L. Meyers, R. K. Leblond Machine Tool Co.; secre-

tary-treasurer, Fred L. Martin, National Metal Trades Ass'n., 706 Elm St.

Executive Committee: W. T. Cowell, Lodge & Shipley Machine Tool Co.; J. H. Nead, American Rolling Mill Co., Middletown, O.; W. R. Fleming, Andrews Steel Co., Newport, Ky.; E. S. Sawtell, Tool Steel Gear & Pinion Co.; Geo. Langen Jr., Advance Tool Co.

NORTH WEST CHAPTER

The North West Chapter of the Society held its May meeting on May 10 in the rooms of the Manufacturers Club. Prof. H. F. Moore, was honor guest for the evening and addressed the members on the "Fatigue of Metals", which was illustrated by lantern slides. Prof. Moore is recognized as one of the foremost authorities on this subject and for some time has been in charge of exhaustive research conducted under the auspices and at the expense of the National Research Council, Engineering Foundation of the Carnegie Institute, and the Experimental Station of the University of Illinois.

The following officers were elected for the coming year: Chairman, Prof. Oscar E. Harder, instructor in metallurgy, University of Minnesota; vice chairman, H. K. Briggs, metallurgist, Minneapolis Electric Steel Castings Co.; secretary-treasurer, Alexis Caswell, secretary Manufacturers Club.

INDIANAPOLIS CHAPTER

The Indianapolis chapter held its May meeting on the 2nd which was addressed by William L. Patterson, of Bausch & Lomb Optical Co., on the "Optics of Metallography." The following officers were elected for the coming year: Chairman, Arthur L. Cramp, general foreman, Lafayette Motors, Indianapolis; vice chairman, Paul O. Deeds, vice president, Deeds & Chapin Co., Indianapolis; secretary-treasurer, Paul Smith, chemist, 122 E. Ohio St., Indianapolis.

HARTFORD CHAPTER

The Hartford chapter held its May meeting on the 12th, at the Hartford Y. M. C. A., when papers were presented by E. L. Wilson, president of Connecticut Electric Steel Co., on "The Electric Furnace", and by Marcus E. Gere, on the "Crucible Process in Manufacture of Steel". Both papers were heartily received, and the discussions following, on "Tungsten" and "Shop Problems", were participated in by most of those present. At this meeting the annual election of officers was also held.

SYRACUSE CHAPTER

The monthly meeting of the Syracuse chapter was held on May 20, in the Hiawatha room of the Onondaga Hotel, when Lt. Col. A. E. White, national president was the honor guest. A dinner at the University Club was tendered Lt. Col. White and was attended by about 100.

The chapter entertained as guests, W. H. Eisenman, national secretary; J. E. Halbing, assistant superintendent of heat treating, Ingersoll Rand Co., Phillipsburg, N. J.; C. E. McQuigg, metallurgist of the Electro-Metallurgical Corp., Buffalo; J. J. Morrow, inspection engineer Steel Co. of Canada, Ltd., Hamilton, Ont.; and members of the Constitution and By-Laws Committee who held an important session in Syracuse on that day.

The following officers for the coming year were also elected: Chairman, Howard J. Stagg, assistant general manager, Halcomb Steel Co.;

vice chairman, F. C. Rabb, metallurgist, 324 Borden Ave.; secretary-treasurer, Wm. F. McNally, metallurgist and chemist, Willys Corp., New Process Gear Div.

DETROIT CHAPTER

The annual dinner meeting of the Detroit chapter was held in the Board of Commerce rooms at 6:30 P. M., on May 31, Lt. Col. A. E. White, being the speaker of the evening. He gave a very interesting presentation of his subject.

One of the most important events of the evening was the presentation to Prof. Edward DeMille Campbell, of a certificate of Honorary Membership in the National Society. This certificate was presented by Lt. Col. White. Prof. Campbell accepted it with an expression of deep appreciation of the honor conferred upon him.

At this meeting the election of officers for the coming year was held, with the following results: Chairman, L. A. Danse, metallurgist Cadillac Motor Co., 4432 Vermont Ave.; vice chairman, H. J. Lawson, general heat treating foreman, Cadillac Motor Co., 568 Hague Ave.; secretary-treasurer, J. L. McCloud, Ford Motor Co., 560 Nona Ave., Dearborn, Mich.

Executive Committee—C. G. Heilman, chemist and metallurgist, General Motors Corp., 5831 Cass Ave.; W. J. Learmonth, superintendent, Plant 4, Studebaker Corp., 8340 Dexter Blvd.; W. G. Calkins, metallurgist, Detroit Twist Drill Co., 1608 Pingree Ave.; A. W. Copeland, president, Detroit Gear Machine Co., 670 E. Woodbridge St.; J. M. Watson, metallurgist, Hupp Motor Car Corp.

NEW HAVEN CHAPTER

The annual meeting of the New Haven chapter was held on May 11 at the Winchester Engineering Club House, when "The Story of Steel" was presented by a series of moving pictures, together with a talk by G. A. Richardson, Midvale Steel & Ordnance Co. The election of officers for the coming year was also held at this meeting.

CHICAGO CHAPTER

The annual meeting of the Chicago chapter was held on May 16 at Steven's Restaurant when John W. O'Leary gave a very interesting discussion on "The Relation of the Steel Treaters to the Present Economic Conditions". The following officers were elected for the ensuing year: Chairman, H. F. Wood, metallurgist, Ingalls Shepard Div., Wyman Gordon Co., Harvey, Ill.; vice chairman, P. A. Lovegreen, superintendent forge shop, Standard Forgings Co., Indiana Harbor, Ind.; secretary-treasurer, Harry Blumberg, metallographist, Illinois Steel Co., South Works, Chicago, Ill.

Members of Executive Committee: F. C. Wheeler, mechanical engineer, Miehle Printing Press & Mfg. Co., Chicago, Ill.; H. T. Moore, metallurgist, Tuthill Spring Co., Chicago; B. R. Kane, foreman heat treating department, Goodman Mfg. Co., Chicago, Ill.

CLEVELAND CHAPTER

The Cleveland chapter held its annual meeting on May 27 at the rooms of the Engineering Society at the Statler Hotel. The paper of the evening was presented by Wm. L. Patterson, research engineer of Bausch & Lomb Optical Co., upon the subject of "The Optics of Metallography". Mr. Patterson gave a very interesting and entertaining de-

scription in detail of the proper use of the microscope in metallurgical laboratories.

The election of officers for the ensuing year was also held with the results as follows: Chairman, Charles G. Shontz, metallurgist, Perfection Spring Co.; vice chairman, R. S. Archer, metallurgical department, Aluminum Castings Corp.; secretary-treasurer, Ray T. Bayless, metallurgist, James H. Herron Co. Members of board of directors, J. V. Emmons, metallurgist, Cleveland Twist Drill Co.; Charles Campbell, superintendent, Pioneer Alloy Products Co.; Prof. H. M. Boylston, professor of Metallurgy, Case School of Applied Science; Samuel L. Hoyt, metallurgical engineer, National Lamp Works, Nela Park.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ADAMS, Jos. O. (M-4), 930 Church St., Indianapolis, Ind.
ANDERSON, Richard (M-5), 2822 Colfax Ave. N., Minneapolis, Minn.
APPEL, W. L. (M-4), 1908 N. Jersey St., Indianapolis, Ind.
ATKINS, G. F. (M-4), 109 E. St. Clair St., Indianapolis, Ind.
BACON, Wm. (M-5), Reed-Prentice Co., 667 Cambridge St.,
BARR, Gilbert J. (M-5), Standard Piston Pin Co., Racine, Wisconsin.
BELLOWS, Hubbard F. (M-5), Walden Worcester Inc., Worcester, Mass.
BOTTOME, Tibbitts R. (M-4), 621 E. 24th St., Indianapolis, Ind.
BROCE, W. T. (M-5), Third Ave. & E St., South Charleston, W. Va.
BUNCOCK, James A. (M-5), 150 Lincoln St., Worcester, Mass.
CARDEN, Alfred G. (M-5), 1305 24th St., Milwaukee, Wis.
CLARK, Earle D. (M-5), Crompton & Knowles Loom Wks., Worcester, Mass.
CRANSTON, Joseph P. (M-5), 304 Maple St., Fort Atkinson, Wis.
DANIELS, C. W. (M-6), 5 Montrole Road, Worcester, Mass.
DIETZMAN, H. M. (M-3), 615 Collings Ave., West Collingswood, N. J.
DOWNEY, N. J. (M-5), 32 William St., Wallingford, Conn.
EKLUND, Oscar F. (M-6), Norton Co., Worcester, Mass.
FARMER, De Lotus (M-4), 1223 Villa Ave., Indianapolis, Ind.
GEHLERT, Wm. E. (M-4), 630 Washington St., Gary, Ind.
GEISSINGER, H. G. (A-4), H. L. W. Mfg. Co., 20th & Fort, Detroit, Mich.
GIBBONS, C. J. (M-5), Worcester Pressed Steel Co., Worcester, Mass.
GRAHAM, Alvin K. (M-4), Kirk-Latty Co., 85th St. & Madison Ave., Cleveland, O.
GROESBECK, E. C. (M-4), 1627 19th St. N. W., Washington, D. C.
HAGADONE, E. B. (M-4), 406 Madison St., Gary, Ind.
HANRAHAN, J. T. (M-4), 2302 Pierson Ave., Indianapolis, Ind.
HAWKINS, E. R. (M-4), Y. M. C. A., Gary, Ind.
HJORTH, O. B. (M-5), Parker Pen Co., Janesville, Wis.
HODGE, John E. (M-5), 1921 Irving Ave. S., Minneapolis, Minn.
HODGEON, Henry (M-3), 463 Dale Ave., Muskegon, Mich.
HOLDEN, Geo. H. (M-3), Naval Ordnance Plant, S. Charleston, W. Va.
HOLM, Carl I. (M-4), Y. M. C. A., Gary, Ind.
HOLMES, J. H. Jr. (A-3), 2031 12th St., Boulder, Colo.
IRONS, W. V. (M-4), University of Buffalo, Buffalo, N. Y.
KALLSTEDT, C. H. (A-3), Peoples Gas Lt. & Coke Co., 1229 S. State St., Chicago, Ill.
KEMP, Felix (M 4), Atlas Crucible Steel Co., Dunkirk, N. Y.

KENNEDY, C. J. (M-4), American Bridge Co., Gary, Ind.
KLANCKE, Hermann (M-5), 613 Plantation St., Worcester, Mass.
KLINKICHT, W. R. (M-5), 318 Piedmont Ave., Cincinnati, Ohio.
KORB, L. F. (M-4), 8644 Hamilton Rd., Detroit, Mich.
KURCZYUSKI, L. (M-4), 1588 N. 12th St., St. Louis, Mo.
LANGHAAR, L. (M-4), Langhaar Ball Bearing Co., Aurora, Ind.
LATHAM, W. E. (M-3), E. Howard Watch Wks., Waltham, Mass.
LEARNED, E. D. (M-5), 11 Foster St., Worcester, Mass.
LEECH, John (M-4), International Silver Co., Bridgeport, Conn.
LEGGE, Elmer E. (M-5), American Steel & Wire Co., Worcester, Mass.
LISK, Alec. M. (M-4), 1959 Scotten, Detroit, Mich.
LONG, C. W. (M-3), 2300 E. Tioga St., Philadelphia, Pa.
LORD, James O. (M-4), 360 Adams St., Gary, Ind.
LUCAS, R. B. (M-4), Illinois Steel Co., Gary Wks., Gary, Ind.
MEYER, E. C. (M-5), Arcade Malleable Iron Co., Worcester, Mass.
MILLER, C. W. (Sb-5), Steel Products Co., 2196 Clarkwood Rd., Cleveland, Ohio.
MONAHAN, J. B. (M-4), Illinois Steel Co., Gary Wks., Gary, Ind.
MORAN, John H. (Sb-5), Ellis Jackson & Co., 18 N. Front St., Philadelphia, Pa.
MORI, Fukutaro (Sb-4), Maeda, Haradamura Mokogun, Hyogoken, Japan.
MORRIS, T. B. (A-4), 2101 Western Ave., Cincinnati, Ohio.
MUNGAN, J. J. (A-4), 617 Ford Building, Detroit, Mich.
McCOMB, Herbert (M-5), 573 Tyler St., Gary Ind.
McCORMICK, Geo. C. (M-5), Crompton & Knowles Loom Wks., Worcester, Mass.
NASH, Francis (M-3), 1521 Green St, Philadelphia, Pa.
NELSON, Geo. W. (M-5), 37 Sterling St., Worcester, Mass.
OBERTING, Chas. (M-4), 1134 Kelly St., Indianapolis, Ind.
OLSEN, Carl L. (M-4), 1310 Beville Ave., Indianapolis, Ind.
PRIESTER, Geo. C. (M-5), University of Minn., College of Engr., Minneapolis, Minn.
PUSITZ, Lubomis (M-4), 1325 Theodore, Detroit, Mich.
RACHEFF, Ivan (M-4), 438 Mass. St., Gary, Ind.
RAMSTROM, D. L. (M-6), Norton Co., Worcester, Mass.
ROBERTS, T. (M-5), C. H. Wheeler Mfg. Co., 18th & Sedgeley Ave., Philadelphia, Pa.
ROBINSON, S. R. (M-4), Sandusky Foundry & Mch. Co., Sandusky, Ohio.
ROTH, Max H. (M-5), Falls Motor Corp., Sheboygan Falls, Wis.
SMITH, G. W. (M-5), Nash Motors Co., Milwaukee, Wis.
SPALDING, Edwin A. (M-5), 29 Oberlin St., Worcester, Mass.
SPENCE, John C. (M-5), 16 Davidson Rd., Worcester, Mass.
SPENCER, W. E. (M-4), Plant No. 3, Studebaker Corp., Detroit, Mich.
SUDDARD, Thos. (M-5), Hamilton Mfg. Co., Two Rivers, Wis.
TERWILLIGER, S. (M-4), 150 Morley, Dearborn, Mich.
TREVELEYAN, H. A. (M-5), 5038 Crane, Detroit, Mich.
WASHBURN, J. M. (M-4), Merrow Machine Co., 28 Laurel St., Hartford, Conn.
WEAVER, Wm. L. (A-5), 315 Partridge St., Albany, N. Y.
WELLS, Chas. A. (M-5), Osgood Bradley Car Co., Worcester, Mass.
WHITE, S. F. (M-6), 18 Euclid Ave., Ludlow, Ky.
WILLETT, John A. (M-4), 1776 Lafayette Blvd., Detroit, Mich.
WILLEY, O. C. (M-4), 4813 Whetzel Ave., Madisonville, Ohio.
WOOD, Jos. E. (M-4), 2186 Madison Ave., Indianapolis, Ind.
WOOD, Wm. P. (M-6), 1348 Wilmot St., Ann Arbor, Mich.
WOODWARD, A. F. (M-4), 621 G. Street, S. W., Washington, D. C.

CHANGES OF ADDRESS

AMMON, Mark A.—from Willys Overland Co., Toledo, Ohio, to Briscoe Motor Co., Flint, Mich.

ANDERSON, Rich.—from 319 Church St., Brooklyn, N. Y. to 319 Church Ave., Brooklyn, N. Y.

BARACH, S. (M-3), from 439 T. St. N. W. Tuxedo Apt. 308, Washington, D. C. to 1439 T. St. N. W. Tuxedo Apt. 308, Washington, D. C.

BARTLETT, J. W.—from Chas. Tractor Corp., Ltd., 28 Atlantic Ave., Toronto, Ont., Can., to Dunn Edge Tool Co., Oakland, Maine.

BEELER, C. F.—from International Harvester Co., Akron, Ohio, to 10117 Adelaide Ave., Cleveland, Ohio.

BERGGREEN, P. H. (M-5), from Room 281, Bureau of Mines, Pittsburgh, Pa. to Foreign Sales Mgr., Reck Heating Co., Ltd., 15 Esromgade, Copenhagen.

BIHLMAN, V. W. (M-3), from 36 Maple St., Springfield, Mass. to 32 Temple St., Springfield, Mass.

BLUMBERG, Harry—from 1424 W. 14th St., Chicago, Ill. to Illinois Steel Company, South Works, Chicago, Ill.

CHABOT, J. M. F.—from 40 Orchard St., Bristol, Conn. to 30 Orchard St., Bristol.

CHAPMAN, V. J. (M-2), from 141 Fairview Ave., Schenectady, N. Y. to 28 Baker Ave., Schenectady, N. Y.

CULP, John F.—from 271 Horton St. to 268 Horton St., Wilkes Barre, Pa.

DALLMAN, O. H.—from Vanadium Alloys Steel Co., 566 W. Randolph St. to 1528 E. 76th St., Chicago, Ill.

DESARIO, John—from 476 Pawling Ave., Troy, N. Y. to Joliette Castings & Forgings Ltd., Joliette, Quebec, Can.

DIEDERICHE, Wm. J.—from Timken Roller Bearing Co., Columbus, O. to 19 Howard St., Waterbury, Conn.

DRAKE, H. P.—from 2072 E. 79th St. to 2066 E. 79th St., Cleveland, Ohio.

DRAY, W. R.—from International Harvester Co., 113 Center St., Akron, O. to University Club, Chicago, Ill.

DULL, C. E. (M-1), from Buchanan, Mich. to 2056 E. 4th St., Room 501, Cleveland, O.

EDSON, C. S. (A-12), from 4873 Edmonton, to 2150 Concord Ave., Detroit, Mich.

FAIRFIELD, J. A.—from Modern Equipment Co., P. O. Box 415, Foxboro, Mass. to 8 Norfolk St., Needham, Mass.

FORRESTER, W. R.—from Milton Mfg. Co., Milton, Pa. to West Main & Center Sts., Grove City, Pa.

FORSBERG, Uno—from The Hess Bright Mfg. Co., Philadelphia, Pa. to care A. B. Sveniska, Kullagerfabriken, Gothenburg, Sweden.

GAMBLE, W. J.—from Vulcan Steam Forging Co., 247 Rano St., Buffalo, N. Y. to Vulcan Steam Forging Co., 221-253 Rano St., Buffalo, N. Y.

GENSTEIN, E. S. (M-9), from 732 Northampton St., Easton, Pa. to 202 Colonial Bldg., Allentown, Pa.

GORHAM, Wm. R.—from No. 81 Bluff, Yokohama, Japan, to No. 53 Aza Kominato, Kitagate Machi, Juniten, Yokohama, Japan.

HALL, H. G.—from 7300 Oglesby Ave., to 7119 Constance Ave., Windsor Sta., Chicago, Ill.

HAMILTON, D.—from 1239 Kingsley St. to 1124 Chelsea Ave., Lansing, Mich.

HOYT, D. G. (M-11), from 719 Ackerman Ave., Syracuse, N. Y. to Savonia, N.

HUERING, H. (M-12), from 100 First Ave., to 1004 First Ave., Charleston, W. Va.

HUMPHREYSVILLE, L.—from 480 E. 112th St. to 11006 Cedar Ave., Cleveland, O.

JANITZKY, E. J.—from Illinois Steel Co., S. Chicago, Ill. to Illinois Steel Co., South Works, Chicago, Ill.

KIEFER, H. G.—from 1457 Field Ave., to 2911 Iroquois, Detroit, Mich.

LAUPEE, A. A.—from 1518 Gratiot Ave., to 1500 Gratiot Ave., Detroit, Mich.

LEVY, Wm. J. (M-9), from 1126 W. Washbourne Ave., to 5939 S. Elizabeth St., Chicago, Ill.

LUTTENAUER, C. (M-12), from 78 Syracuse St., Baldwinsville, N. Y. to 713 Spaulding St., Elmira, N. Y.

MCCONNELL, J.—from 4752 Ellis Ave., to 2605 E. 73rd St., Windsor Park Sta..

McDERMOTT, C. C.—from Brown Instrument Co., 111 W. Washington St. to Brown Instrument Co., Conway Bldg., Chicago, Ill.

MCPHERSON, V. J.—from 111 Broad St. to 24 Summer St., Claremont, N. H.

MEEHAN, W.—from U. S. Armory, 36 Maple St., to 32 Temple St., Springfield, Mass.

MITCHELL, F.—from 410 E. 9th St. to 1710 E. Jackson St., Muncie, Ind. Chicago, Ill.

NELSON, John—from 958 College Ave., Beloit, Wis. to Royal Oak, Mich.

NISBEL, Geo. B.—from Erie Smelting & Iron Co. to 643 W. 8th St., Erie, Pa.

PATTERSON, C. T.—from 244 Buckingham Ave., Syracuse, N. Y. to 112 Summit Ave., Solvay, N. Y.

PETERSON, Carl—from 62 Weybosset St., Providence, R. I. to Providence Gas 62 Weybosset St., Providence, R. I.

PHILPOTT, A. D.—from 19 Chalfern Apts., Mansfield, Ohio, to R. F. D. Ventura, Cal.

PUTNAM, A. H.—from Rock Island Arsenal, Rock Island, Ill. to P. O. Box 653, Davenport, Iowa.

ROBINSON, J. W.—from 1305 Seventh St., Port Huron, Mich. to C. H. Wills & Co., Marysville, Mich.

ROSEN, Joe—from Rock Island, Ill. to Linograph Co., Davenport, Iowa.

SCHWAN, Christian—876 to 28th St., Milwaukee, Wis.

SHIPMAN, G. F.—from Washington, N. J. to 404 Thomas St. Phillipsburg, N. J.

SICARD, A. J.—from Ingersoll-Rand Co., Athens, Pa. to 149 Passaic St., Hack-

SMITH, W. R.—from 306 W. Pike St., Cannonsburg, Pa. to 652 Dewey Ave., Bridgeville, Pa.

STORY, J. M.—from 1525 Guardian Bldg., to Bethlehem Steel Co., 1525 Guardian Bldg., Cleveland, Ohio.

SULLIVAN, L. D.—from 1558 Penobscot Bldg. to 4843 Bellevue Ave., Chicago.

SWAN, Christian—from 648 26th St., Milwaukee, Wis.
ensack, N. J.

THEIS, John—from Vanadium Alloys Steel Co., 5933 Haverford Ave., to Vanadium Alloys Steel Co., 601 Franklin Trust Bldg., Philadelphia.

TISDALE, N. F. (M-3), from 11 St. James Ave., to 47 Johnson St., Springfield, Mass.

WALTHER, F. F. (A-1), from 1012 Citizens Bldg. to 414 Union Bldg., Cleveland, O.

WELLS, Glenn H.—from Amer. Locomotive Co., Schenectady, N. Y. to 1141 E. 144th St., Cleveland, Ohio.

WHITE, C. V.—from 225 N. Court St., to 1239 Fairview Ave., Rockford, Ill.

TRANSACTIONS
of the
American Society for Steel Treating

Vol. 1 Cleveland, July, 1921 No. 10

WHEN WILL INDUSTRY RESUME?

With the slowing down of business during the past nine months, practically every industry in the country has been affected. The tapering off of operations when compared with the relatively high level of the early months of 1920 seems greatly pronounced. As an indication as to the extent of decline in business, the iron and steel industry with its continually falling output of raw materials, especially pig iron and steel ingots, offers excellent data for consideration. For seven consecutive months production figures have continued to decline and from all indications at present will continue to fall, since not one ripple on the surface points to an early revival of trade. Even authorities in economic problems hesitate to base predictions upon analyses of conditions as they exist today.

According to figures compiled monthly by *The Iron Trade Review* production of coke and anthracite pig iron in May reached the lowest point on record since June, 1908, a period of 13 years. This fact alone while significant is greatly magnified when it is stated that the pig iron producing capacity of the United States is far in excess of that of 1908, due to the increased demand for iron during recent years. It is safe to assume that the present manufacture of pig iron is not over 35 per cent of the potential capacity of blast furnaces, based on previous high point years. In October, 1920, pig iron produced was at the rate of 106,075 gross tons per day and was the second highest month of 1920. In May, 1921, the daily rate had fallen to 39,199 tons and represented but 37 per cent of the October figure. Both iron made for sale and iron made for conversion to steel has suffered loss, although the former has been the most seriously affected. Part of the merchant iron loss may be assigned to the almost complete shut down of gray iron foundries, which have supplied the automotive industry with castings.

The country possesses 436 blast furnaces and on Sept. 30, 1920, 317 of these were in production. Month by month the number of stacks has been reduced until on May 31, but 89 were in operation, 228 having been blown out during the eight months. Thus in May, only 28 per cent of the October stacks were in blast and only 20.4 per cent of the total stacks in the country. The 89 furnaces were the lowest number active on record.

Steel ingot production as well as pig iron has undergone a decline since last fall. According to figures compiled by the American Iron and Steel Institute, ingots produced in May were approximately 1,500,000 gross tons. In October, 1920, the output was approximately 3,680,000

gross tons. The present rate of manufacture is 40.5 per cent of that of eight months ago.

Comparison of these figures with declines in previous periods of depression shows that at no time in modern history has curtailment been so drastic or so extended. Thus in this respect conditions differ widely. The question now on every lip is when will the bottom be reached and how rapidly will operations pick up once they are started on the up grade.

ALLOY STEEL OUTPUT FOR 1920 HOLDS UP

Production of alloy steel ingots and castings during 1920 was the second highest on record, according to a report of figures compiled by the American Iron and Steel Institute. The tonnage aggregated 1,660,292 gross tons, a gain of 179,104 tons or 10.8 per cent over the 1919 figure of 1,481,188 tons and but 127,560 tons less than the 1,787,852-ton high record of 1918. Of the 1920 total, 1,591,939 tons were steel ingots and 68,353

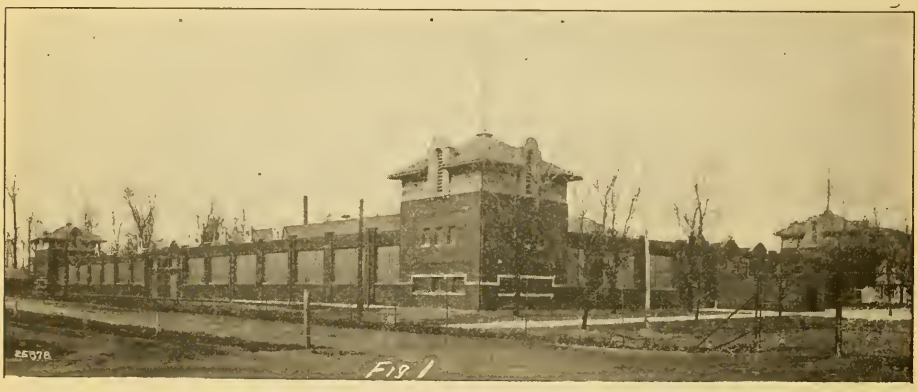


FIG. 1—MANUFACTURES BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE THIRD ANNUAL EXHIBITION OF THE AMERICAN SOCIETY FOR STEEL TREATING WILL BE HELD, SEPT. 19-24

tons were steel castings. Corresponding figures for previous years were: In 1919, ingots 1,435,816 tons and castings 45,372 tons; in 1918 ingots 1,721,367 tons and castings 66,485 tons.

The 1920 tonnages of alloy ingots were divided according to process as follows: Open-hearth basic 1,116,923; open-hearth acid 129,832; bessemer 81,809; crucible 29,513; and electric and miscellaneous steel 233,862 tons. Corresponding tonnages for 1919 were: Open-hearth basic 1,056,137; open-hearth acid 114,923; bessemer 66,581; crucible 22,600; and electric and miscellaneous 175,575 tons. It is interesting to note that the greatest relative gain was made in the electric and miscellaneous processes, the increase over 1919 being 33 per cent.

REDUCED RATES TO INDIANAPOLIS

We are very glad to announce that the railroads of the country, through the Central Passenger Association, have granted fare and a half round trip for members of the Society and their dependents, for the Indianapolis Convention and Exhibition, Sept. 19 to 24. A large number of members and guests are always in attendance at this Convention, thus the railroads unanimously decided to recognize the Society to the extent of granting the fare and a half for the round trip.

FIG. 2—INTERIOR OF MANUFACTURES BUILDING, SHOWING A PART OF THE 76,000 SQUARE FEET OF FLOOR SPACE TO BE USED BY THE EXHIBITORS

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification certificate must be presented to the ticket agent for the purchase of the round trip ticket. This identification certificate will be mailed to all the members of the Society before the first of September.

The reduction of railroad fares will contribute materially to an increase in attendance and there is no doubt but that the number visiting Indianapolis will be in excess of the 10,000 in attendance at Philadelphia.

FIG. 3—WOMAN'S BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE SESSIONS OF THIRD ANNUAL CONVENTION OF THE SOCIETY WILL BE HELD

HOTELS IN INDIANAPOLIS

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reservations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then take the letter with you to present to the hotel clerk at Indianapolis when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$2.00 up " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$2.50 to $4.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 "	not over $3.50 " "
Haugh Hotel	60 "	" " " " "
Linden Hotel	250 "	" " " " "
Majestic Hotel	59 "	" " " " "
Roosevelt Hotel	187 "	" " " " "
Royal Hotel	85 "	" " " " "

SPACE RESERVED AT INDIANAPOLIS EXHIBITION

Reservations for space at the Convention and Exhibition at Indianapolis, Sept. 19-24, are coming in at such a rate as to bring forth the probability that every available space will be taken when the Convention opens on Sept. 19. The attendance during the coming Convention will be up to, if it does not exceed the expectations of the Board of Directors. Information the board receives from the membership and from manufacturing plants indicates that they are going to take the opportunity to attend this Convention inasmuch as they desire to incorporate and place into effective operation any equipment and material which may increase the efficiency in their plants.

The latest list of exhibitors whose products will be on exhibition at the Convention follows:

Selas Co., economic gas appliances in operation 3
Charles Englehard, temperature control and recording instruments in operation 4
Smith Gas Engineering Co., producer gas machines in operation. 7
George J. Hagen Co., oil and gas furnaces in operation 8 9
Westinghouse Elec. & Mfg. Co. electric appliances in operation .....A-B
Brown Instrument Co., recording instruments in operation 17
Midvale Steel & Ordnance Co., operating exhibit of steels 18
Indianapolis Drop Forging Co., forgings in operation 19
Eaton Electric Furnace Co., electric furnaces in operation 20
Calorizing Co. of Pittsburgh, calorizing process in operation 21
Deeds Commercial Laboratories, carbonizing compounds in operation..... 22
Leeds & Northrup Co., electric furnaces and pyrometers in operation 36-23
Bausch & Lomb Optical Co., metallographic instruments in operation..... 24
Tate-Jones Co., Inc., furnaces 25
Armstrong Cork & Insulating Co., insulating materials 27
Taylor Instrument Co., in operation 28
Ludlum Steel Co., steels 43-30
Marschke Mfg. Co., electric grinders and buffers in operation 31
Quigley Furnace Specialties Co., furnace specialties in operation 32
Hoskins Mfg. Co., electric furnaces and recording instruments in operation.. 33
Simonds Mfg. Co., steels and saws in operation 34
General Electric Co., electric furnaces in operation 35
William Ganschow Co., gears 37
Bristol Co., recording instruments in operation 40
Bethlehem Steel Co., steels 57-44
Spencer Turbine Co., blowers in operation 45
Driver Harris Co., alloy pots and boxes 49
Crucible Steel Co. of America, steels 63-51-50
Electric Steel Co. of Indiana, castings 55
Penton Publishing Co., "The Iron Trade Review" 58
Witherow Steel Co., continuous die forming 62
Halcomb Steel Co., steels 82-69
Atlas Crucible Steel Co., steels 83-70
Bell & Gossett, case hardening materials 74
The Iron Age, publications 75
Deeds & Chapin, "Cinch" cement 81
Case Hardening Service Co., carburizing compounds 87
General Alloys Co., alloy pots and boxes 107-94
Electrical Refractories Co., refractory materials 95
W. S. Rockwell Co., oil and gas furnace 99
Electric Alloy Steel Co., alloy steels..... 100
Colonial Steel Co., steels 108
Herman A. Holz, Inc., metallurgical equipment 119
Bureau of Standards, research work 124
Imperial Drop Forging Co., forgings 120
Vanadium Alloy Steel Co., steels 125
Heppenstall Knife & Forge Co., die blocks 126
E. C. Atkins Mfg. Co. metal saws and cutting machines 153
Mahr. Mfg. Co., furnaces .....Unassigned
Dearborn Chemical Co., oils and rust preventatives .....Unassigned
Central Steel Co., alloy steel .....Unassigned
Celite Products Co., insulating materials in operation 39

PROPOSED CHANGES TO THE CONSTITUTION

On May 18, the Constitution and By-Laws Committee, composed of C. E. McQuigg, metallurgist of the Electro-Metallurgical Co.; J. E. Halbing, assistant superintendent of heat treating of the Ingersoll Rand Co.; J. G. Morrow, inspection engineer of the Steel Company of Canada; held a meeting in Syracuse, and proposed the following changes to the Constitution and By-Laws of the American Society for Steel Treating.

According to the present Constitution, these changes were first submitted to the Board of Directors and the changes were approved by a two-thirds vote of the Board.

In addition to publication in the Transactions, a copy of these proposed changes will be sent to all the members, and at the expiration of 60 days a voting ballot will be mailed to members so that they may vote upon the proposed changes.

PROPOSED AMENDMENTS TO THE CONSTITUTION AMERICAN SOCIETY FOR STEEL TREATING

Article V, Section 4

Now reading:

Section 4. A member shall be a person engaged in work relating to the arts and sciences of iron or steel who is twenty-one years of age or over and who is not engaged in the actual solicitation of orders for metals, materials, supplies, equipment, or apparatus of whatsoever nature used in the art, nor any administrative officer ranking in authority over the sales department of any firm engaged in such trades.

To be amended to read as follows:

Section 4. A member shall be a person engaged in work relating to the arts and sciences of iron or steel who is 21 years of age or over and who is not in the Sales Department of any firm dealing in or manufacturing metals, materials, supplies, equipment or any apparatus of whatsoever nature used in the art.

Article V, Section 5

Now reading as follows:

Section 5. An associate shall be a person engaged in work relating to the arts and sciences of iron or steel who is twenty-one years of age or over, and who is engaged in the actual solicitation of orders for metals, materials, supplies, equipment, or apparatus of any nature used in the art, or an administrative officer working in authority over the sales department of any firm engaged in such trades.

To be amended to read:

Section 5. An associate member shall be a person engaged in work relating to the arts and sciences of iron or steel who is 21 years of age or over, and who is in the Sales Department of a firm dealing in or manufacturing metals, materials, supplies, equipment, or apparatus of whatsoever nature used in the art.

Article V, Section 8

Now reading:

Section 8. Honorary members and members are entitled to vote and hold office. Associates, sustaining members and juniors are not entitled to vote or hold office, but are entitled to all other privileges of membership. Honorary members and members are entitled to vote on all questions brought before the membership at any meeting, in person, by mail, or by a proxy given to a person entitled to vote. A proxy shall be given and shall be valid for the decision or vote upon only such matters as shall be indicated on the face thereof, and no proxy shall be valid for a greater length of time than three months.

To be eliminated in its entirety, and sections 8 and 9 as follows, to be substituted:

Section 8. All classes of members except juniors are entitled to vote on all questions brought before the membership at any meeting: in person, by mail or by a proxy given to a person entitled to vote. A proxy shall be given and shall be valid for the decision or vote upon only such matters as shall be indicated on the face thereof, and no proxy shall be valid for a greater length of time than three months.

Section 9. Honorary members, members and sustaining members whose qualifications entitle them to member classification, may hold office. Associates and sustaining members whose qualification place them in the associate classification are entitled to hold office on executive committees of local chapters, except the offices of chairman and vice chairman, and to appointment on National committees. The number so elected or appointed, however, must always be a minority on any given committee.

Article VI, Section 2

Now reading as follows:

Section 2. All applications for admission for membership as members, associate, juniors, or sustaining members shall be accompanied by initiation fee and be presented

to the Executive Committee of the local chapter, which shall consider and act upon each application, assigning each approved applicant to the grade of membership to which, in the judgment of said Executive Committee, his qualifications entitle him. In the absence of a local chapter, application for membership to the Society shall be made to the Board of Directors, which Board shall act in the same manner as said Executive Committee.

To be amended to read:

Section 2. All applications for admission for membership as members, associate members, junior members, or sustaining members, shall be presented, accompanied by initiation fee when such is required, to the executive committee of the local chapter, which shall consider and act upon each application, assigning each approved applicant to the grade of membership to which, in the judgment of said executive committee his qualifications entitle him. In the absence of a local chapter, applications for membership in the Society shall be made to the Board of Directors, which Board shall act in the same manner as said executive committee.

Article VI, Section 6

Now reading:

Section 6. The initiation fees for membership shall be as follows:

For Member	$ 3.00
For Associate	10.00

To be amended to read:

Section 6. The initiation fees for membership shall be as follows:

For Member	$ 3.00
For Associate Member	3.00
For Sustaining Member	*No fee*
For Junior Member	*No fee*

Article VIII, Section 11

Now reading:

Section 11. The President or any member of the Board of Directors shall not be eligible for immediate re-election to the same office then held, at the expiration of the term for which he was elected.

To be amended to read:

Section 11. The President, or any member of the Board of Directors with the exception of the Secretary and Treasurer, shall not be eligible for immediate re-election to the same office then held, at the expiration of the term for which he was elected.

Article XIV, Section 1

Now reading as follows:

Section 1. Amendments to the Constitution may be effected in the following manner: The Board of Directors may, by affirmative vote of two-thirds of its entire membership, propose amendments, which must be submitted by letter to the voting membership of the Society. Not less than two months following the mailing of such proposed change a ballot shall be mailed to each member, to be returned to the Society's headquarters not later than one month following the date of its issue, and the result of a majority of such ballots returned shall govern.

To be amended to read:

Section 1. Amendments to the constitution may be effected in the following manner: The Board of Directors may, by affirmative vote of two-thirds of its entire membership, propose amendments which must be submitted to the voting membership of the Society. In not less than two months following the notification of such proposed change, a ballot shall be mailed to each voting member to be returned to the Society headquarters not later than one month following the date of its issue, and the result of a majority of such ballots returned shall govern.

PROPERTIES AND MICROSTRUCTURE OF HEAT TREATED NONMAGNETIC, FLAME, ACIDS AND RUST RESISTING STEEL

By Charles M. Johnson*

(A Paper Presented Before Several Chapters of the Society)

The writer has made a study of the steels about to be described covering a period of a year or more, originally with a view to producing a steel that could be forged, rolled or sheared in thicknesses of 0.01 to 1 inch or more and offering a maximum resistance to attack by oxyacetylene flame.

It was also demanded that the steel be machinable and that holes could be drilled in the same. As the results now stand, a steel has been produced that has certain unusual properties which are briefly described in the tabulations that follow.

As to the nonmagnetic features, a permanent horseshoe magnet which is capable of suspending in the air a 500-gram weight, will attract only the finest particles. Or if a piece of the steel be shaped into a compass needle supported on a needle point bearing, it is attracted but slowly if a magnet of the size mentioned be brought to within a distance of about ½-inch of the end of the needle.

The following report was received on these steels: "Neither the Esterline nor the Leibling apparatus showed any indication that either

*Director of research department, Crucible Steel Co. of America, Pittsburgh.

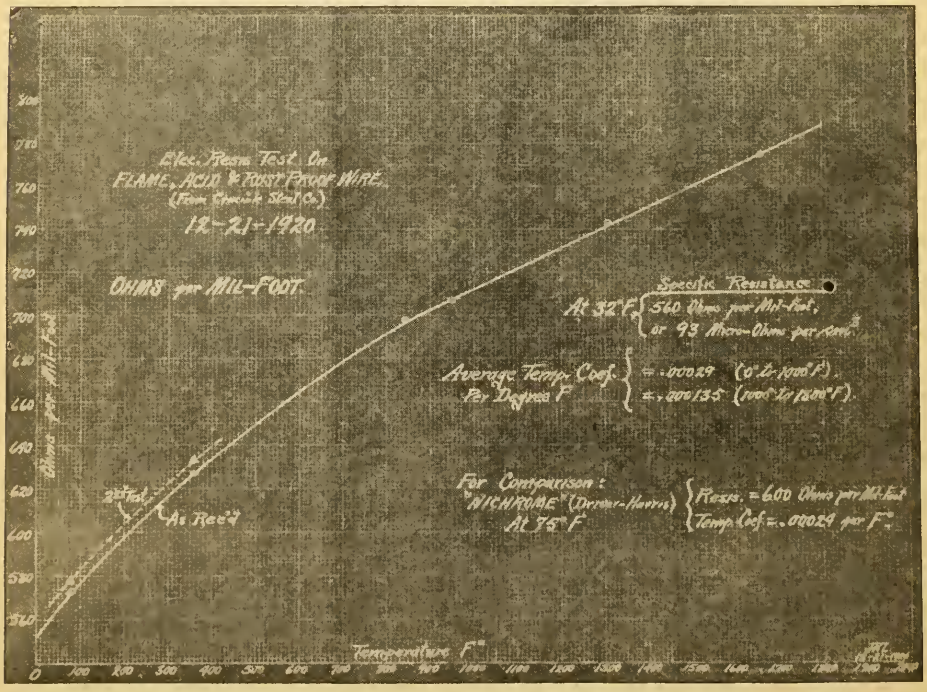


Fig. 1—Chart showing electrical resistance of grade No. 3 nonmagnetic, flame, acids and rust resisting steel at various temperatures.

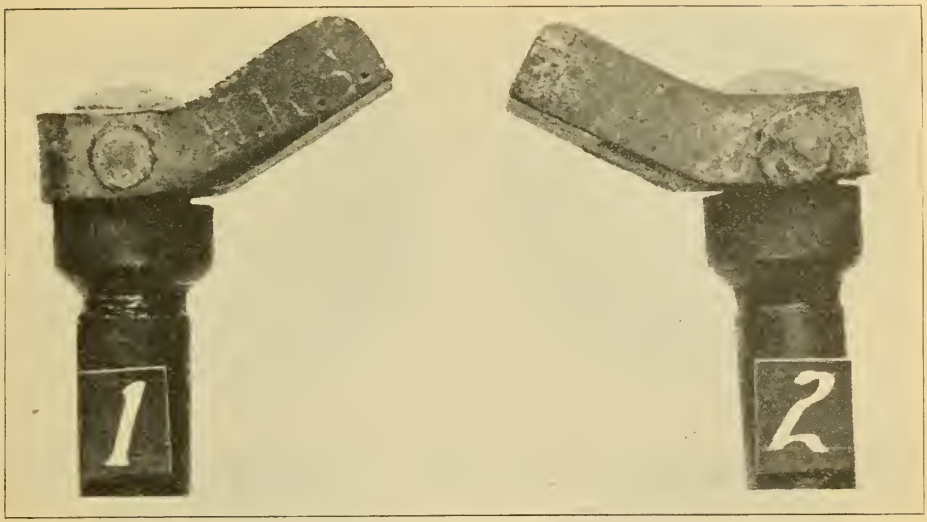


Fig. 2—Resistance of grade No. 2 nonmagnetic, flame, acids and rust resisting steel to products of combustion of fuel oils, etc. Spoon No. 1 used continuously for 110½ hours at 1500 to 1800 degrees Fahr. in combustion chamber of diesel engine burning kerosene and distillate. Spoon No. 2 used at same temperature for 103 hours in engine burning fuel oil. Both are still perfect.

grades No. 2 or No. 3 could be magnetized in the natural bar or after quenching in oil or water. The permeability in respect to air is 1.04, and after oil treating 1.06 (H Max 300.) The residual magnetism after charging did not exceed four lines per square centimeter. Both of these samples in all three conditions can be considered nonmagnetic." Also it has been noted that prolonged heat will cause an increase in its attraction by a magnet. The cumulative effect of many hours heating at the most favorable temperature has been studied.

After a number of hours heating of Grade No. 2 of these steels at a temperature approximating to 1300 degrees Fahr. it was noted that there was a decided increase in its attraction to a magnet. This increase in the attraction of this steel to a magnet was entirely lost by heating it to about 1600 degrees Fahr. for a few minutes and cooling it in air or quenching it in water.

A ¾-inch square bar of Grade No. 2 was placed in a flue and held at a temperature above a red heat for a month. The temperature given was stated as "approximate". This piece weighed 262 grams. The permanent magnet just lifted it from the table. On heating it at 1600 degrees Fahr. for 5 to 10 minutes and cooling in the air, this increase of attraction to the magnet was gone. Brinell before demagnetizing was 300 and after demagnetizing was 217. So far, the Grades No. 3 and No. 4 have not shown this gain in attraction to the magnet on prolonged heating. These same grades are lower in magnetic susceptibility than manganese steel.

The lowest temperature at which Grade No. 2 loses its slight increased magnetic susceptibility is close to 1500 degrees Fahr. (815 degrees Cent.) for instance, after so short a period of heating as 10 minutes. This slight gain in magnetic susceptibility can be restored after demagnetizing at 1500 degrees Fahr. in the same short period of 10 minutes by again heating at about 1200 degrees Fahr. If it be heated at about 1350 degrees Fahr., no restoration occurs except perhaps after several hours heating.

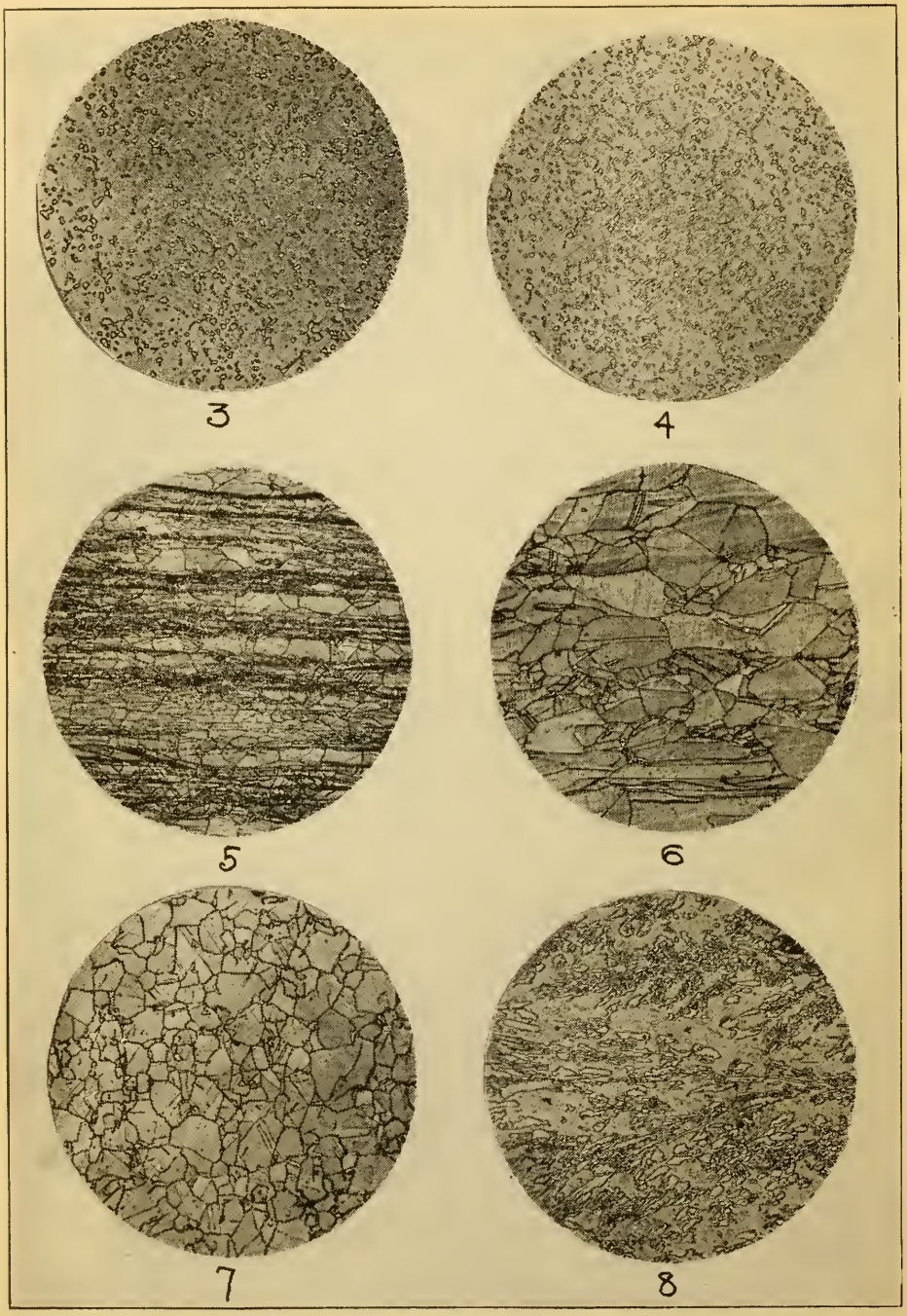


Fig. 3—Photomicrograph × 300 of grade No. 2 in slightly magnetic condition. Heated one month in flue at 1600-1700 degrees Fahr. Brinell 302. Fig. 4—Same as Fig. 1 demagnetized. Brinell 217. Fig. 5—Transverse section of grade No. 2 sheet steel etched × 300 before treatment in liquid air. Fig. 6—Same as Fig. 5 immersed in liquid air 10 minutes. Fig. 7—Transverse section of grade No. 2 natural hammered bar × 300. Brinell 228. Fig. 8—Transverse section of grade No. 3 natural ingot × 300. Carbon 1.65 percent. Brinell 302.

It is of interest to note in this connection that high carbon manganese steel of the Hadfield type shows a similar slight increase of magnetic susceptibility at about 1200 degrees Fahr. but more so at 1100 degrees Fahr. after 10 minutes heating and loses this increased susceptibility, also at about 1500 degrees Fahr. after 10 minutes. The cold drawing of Grade No. 3 increases its magnetic susceptibility to a noticeable extent. To remove this increase of susceptibility, steel is heated to 1900-2000 degrees Fahr. for a few minutes; cooled in air and heated again if necessary.

Three grades of nonmagnetic, flame, acids and rust resisting steel were immersed in boiling liquid air for 10 minutes together with a piece of ordinary sheet steel and a piece of 25 per cent nickel steel. The 25 per cent nickel steel showed a strong magnetic susceptibility about the same as ordinary steel, but inside of a minute after removing it from the boiling air, this effect was entirely gone. The three grades of nonmagnetic, flame, acids and rust resisting steel were not attracted by the magnet immediately after removing from the liquid air or when still immersed.

It was also found that while the ordinary sheet steel on being taken out of the liquid air was very brittle and could be snapped off with a pair of pliers, the nonmagnetic, flame, acids and rust resisting steel and also 25 per cent nickel steel were apparently as tough as ever, showing no indication of brittleness. Therefore, the hot rolled nonmagnetic, flame, acids and rust resisting steel can be described as tough and strong in all temperatures from — 185 degrees Cent. to + 1300 degrees Cent. which is a fairly good range. This ought to make very good material for bottles for transporting liquid air as it did not become brittle at the lower temperature.

Table I shows resistance to acids of nonmagnetic, acids, flame and rust resisting steel compared to some other metals and steels. The metals were in sheet form and immersed for 24 hours at room temperature in the following acids: Glacial acetic, 20 per cent H_2SO_4, 32 per cent HNO_3 and 19 per cent HCl. The loss in weight is given in milligrams per square inch of exposed surface.

The tests, of course, were made on samples from which all scale had been removed either by grinding or polishing.

It was an interesting fact that in some of the grades, the scale was dissolved by glacial acetic acid, discoloring the acid whereas the steel from which the scale had been thoroughly ground off showed no loss of weight and did not discolor the acid.

Table I

Nonmagnetic, Flame, Acids and Rust Resisting Steel

Grade	Glacial Acetic	32 per cent H_2SO_4	10 per cent H_2SO_4	32 per cent HNO_3	19 per cent HCl
No. 5-2		2.0			
No. 4-2	6.15	3.3	3.2	0.41	33.3
No. 3-2	0.33	6.3	5.4	0.50	41.0
No. 2-2	0.26	86.1	68.3	0.26	99.2
No. 2-2 oil 2000°F	0.15	85.9	50.8	0.93	67.1

Other Metals and Steels

Grade	Glacial Acetic	20 per cent H_2SO_4	10 per cent H_2SO_4	32 per cent HNO_3	19 per cent HCl
High Cr Ni Steel	7.93	1,045.0	111.3	0.27	462.8
High Cr Si Steel	0.00	2,180.0	..	0.50	...
25% Ni Steel	7.81	9.0	11.0	1,683.00	22.3
38% Ni Steel	13.80	4.1	4.1	3,459.00	19.0
Wrought Iron	19.30	1,122.0	490.0	1,715.00	261.5
Copper Steel	12.20	96.3	73.4	2,126.00	201.2
Monel Metal	0.70	1.2	1.3	2,157.00	13.1
High Cr Steel	0.67	2,062.0	1,262.0	0.10	437.3

Following are the results of immersing nonmagnetic, flame, acids and rust resisting steel in cold concentrated nitric acid of 1.42 specific gravity for 24 hours:

Grade	Loss per square inch
No. 2	0.37 milligram
No. 3	0.36 "
No. 4	0.37 "

The high polish of the samples was uneffected by the acid.

Table II demonstrates how this class of steel has an extraordinary high reduction and elongation at temperatures that would burn anything but high speed steels. Grade No. 2 attracts attention in this respect, that even at 2450 degrees Fahr. the reduction is 69.3 per cent, elongation 65 per cent in 2 inches and tensile strength 103,090 pounds per square inch. Grade No. 3 at 2200 degrees Fahr. had a reduction of 64.3 per cent elongation 58.5 per cent and tensile strength of 111,170 pounds per square inch.

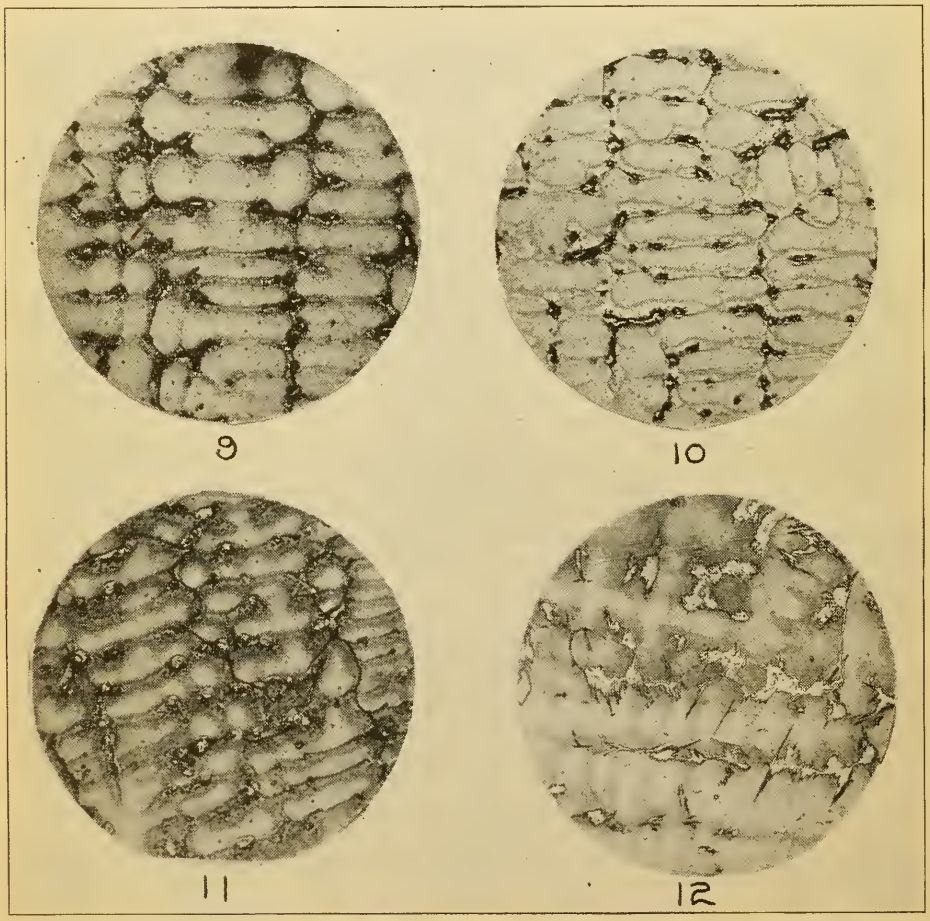


Fig. 9—Microstructure of transverse section of natural ingot grade No. 2. Brinell 179. Fig. 10—Same of grade No. 3 Brinell 187. Fig. 11—Same of grade No. 4. Brinell 166. Fig. 12—Transverse section Hadfield's manganese steel natural ingot. Brinell 302.

Tensile Strength of Cast Ingots Made From Nonmagnetic, Flame, Acids and Rust Resisting Steel, Grade No. 4

Elastic Limit	47,400 pounds per square inch
Ultimate Strength	84,480 pounds per square inch
Elongation	19.5 per cent
Reduction	16.6 per cent

This is the natural casting before it has had any annealing or heat treatment.

Table II

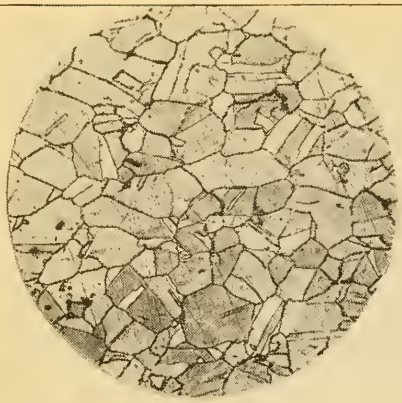
Tensile Values of Nonmagnetic, Flame, Acids and Rust Resisting Steel Hammered Bars

Grade	Yield point lbs. per sq. in.	Ultimate strength lbs. per sq. in.	Elongation in 2 in. per cent	Reduction of area per cent	Brinell	Treatment	
No. 2-1	107,270	146,870	25.5	40.1	302	Natural condition	
No. 2-1	67,750	130,000	37	46.3	228	*Quenched in air	1832° F.
No. 2-1	67,000	125,800	40.5	54.1	241	" " oil	1832
No. 2-1	79,720	131,020	37.5	49.6	241	" " water	1832
No. 2-1	53,990	103,090	65	69.3	187	* " " oil	2450
No. 2-1	56,650	109,500	67.5	67.5	187	" " oil	2400
No. 2-1	56,080	113,190	60.5	63.3	202	" " oil	2300
No. 2-1	62,000	118,400	54.5	62.3	217	" " oil	2200
No. 2-1	75,190	134,330	35	45.	269	" " oil	1650
No. 2-1	105,480	140,660	27.5	41.7	293	" " oil	1475
No. 3-2	85,710	117,990	33	48.2	228	Natural condition	
No. 3-2	61,340	111,170	58.5	64.3	196	Quenched in oil	2200° F.
No. 3-2	62,080	112,680	49	62.4	207	" " oil	2100
No. 3-2	72,700	111,650	45	61.3	228	" " oil	2000
No. 3-2	75,080	113,140	39	60	228	" " oil	1900
No. 4-5	90,220	113,030	31.5	49	228	Natural condition	
No. 4-5	55,900	110,250	47.5	60.3	187	Quenched in oil	2200° F.
No. 4-5	59,200	110,900	42.5	57.3	187	" " oil	2100
No. 4-5	56,490	107,370	44	56.8	192	" " oil	2000
No. 4-5	62,000	109,400	38.5	52.7	192	" " oil	1900

*Periods of heating 15 minutes after reaching the above temperatures.

Nonmagnetic, Flame, Acids and Rust Resisting Hot Rolled Steel Sheets. Grade No. 2-6

	Treatment	Yield point by dividers lbs. per sq. in.	Tensile lbs. per sq. in.	Per cent elongation in 2 inches	Per cent reduction in 2 inches	Shore
600° C.	air	83,950	114,600	49	45.1	50
600	oil	89,440	115,840	54.5	45.5	45
600	water	85,320	118,930	48.5	44	44
650	air	79,940	115,634	52.5	45.1	44
650	oil	94,190	120,930	51.2	41.3	45
650	water	91,575	115,700	46.5	40.4	45
700	air	91,130	122,320	29	29.1	50
700	oil	89,500	127,000	33	36.9	50
700	water	89,190	123,120	35	33	48
850	air	92,540	134,330	25.5	21.8	50
850	oil	83,530	135,330	33	30.2	50
850	water	81,270	133,530	30.5	26.6	50
900	air	79,620	130,250	33.5	28.3	50
900	oil	75,760	137,880	38.5	33.9	50
900	water	77,430	130,410	36.5	36.4	50
950	air	71,430	131,190	37	30.9	50
950	oil	74,295	131,040	41	37.9	50
950	water	79,310	130,720	40.5	37.6	50
1050	air	74,710	119,540	44	42.5	48
1050	oil	76,500	118,310	42.5	47	47
1050	water	75,370	121,670	43	39.9	46
1100	air	66,370	122,600	51	50.5	45
1100	oil	68,170	125,820	53.5	50.8	44
1100	water	64,850	115,600	47	44.7	43
1200	air	54,890	116,020	64	42.7	38
1200	oil	56,270	114,290	59.5	51	40
1200	water	55,700	98,250	59.5	47.2	36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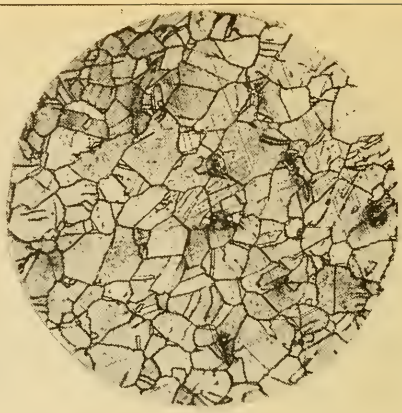
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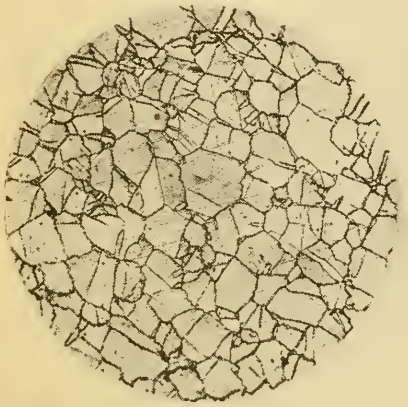
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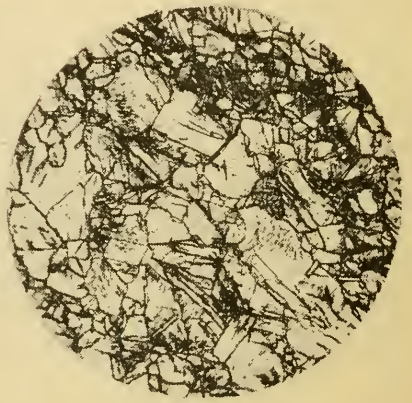
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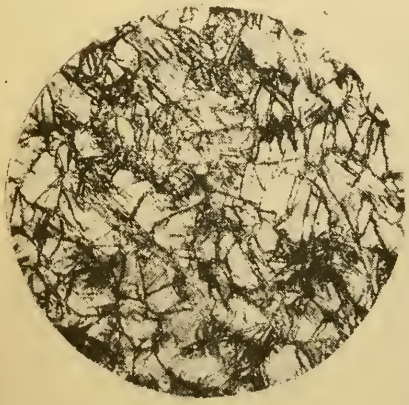
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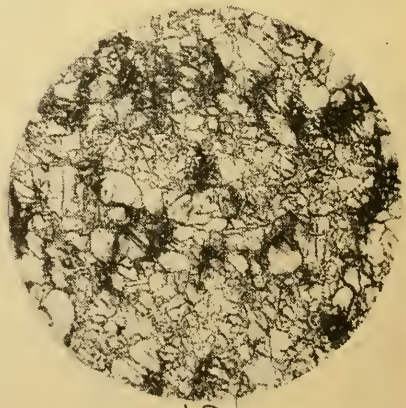
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Transverse sections of microstructure × 300 and hardening at ascending temperatures of grade No. 2-2 air cooled. All specimens held two hours including 750 degree Cent. treatment. Fig. 13—500 degrees Cent. Brinell 241. Fig. 14—550 degrees Cent. Brinell 241. Fig. 15—600 degrees Cent. Brinell 241. Fig. 16—650 degrees Cent. Brinell 255. Fig. 17—700 degrees Cent. Brinell 286. Fig. 18—750 degrees Cent. Brinell 286.

1-Inch Square Rolled Bar, Natural Condition. Grade No. 3-10

Elastic limit by strain gauge lbs. per sq. in.	Yield point by dividers lbs. per sq. in.	Tensile lbs. per sq. in	Elongation in 2 inches	Reduction in 2 inches	Brinell
90,500	99,500	134,250	29	49.2	269

Nonmagnetic, Flame, Acids and Rust Resisting Hot Rolled Sheet Steel. Grade No. 3-8

	Treatment	Yield point by dividers lbs. per sq. in.	Tensile lbs. per sq. in.	Elongation in 2 in., per cent	Reduction in 2 in., per cent	Shore
600°C.	air	114,620	126,900	32.5	39.7	55
600	oil	117,350	127,000	22.5	36.3	57
600	water	111,600	126,900	25	37.9	55
650	air	117,750	165,680	30	39.1	50
650	oil	114,680	130,580	31.5	39.1	50
650	water	112,250	130,000	33.5	38	53
700	air	107,690	133,730	28.5	38.4	48
700	oil	101,180	128,990	34.5	35.5	47
700	water	99,390	131,020	29	37.9	50
850	air	96,690	126,130	30	37.8	47
850	oil	100,290	124,780	31	35.3	45
850	water	98,500	131,340	31	37.9	47
900	air	86,110	128,400	32.5	38.8	48
900	oil	98,480	131,400	33	39.6	48
900	water	97,820	126,390	34	40.9	45
950	air	99,100	134,600	33.5	41.9	45
950	oil	87,730	132,820	33	41.4	45
950	water	92,070	129,270	34.5	40.2	47
1050	air	74,040	122,420	45	43.3	38
1050	oil	74,610	122,910	47	43.7	40
1050	water	78,710	120,690	45	45.7	40
1100	air	64,460	122,590	50	46.9	38
1100	oil	61,560	115,610	52.5	47.4	40
1100	water	73,410	116,400	49.5	48.7	40
1200	air	67,200	108,700	51.5	47	37
1200	oil	67,900	109,120	62.5	46.9	33
1200	water	57,900	99,400	60	51.1	38

Tensile Strength at High Temperature of Grade No. 3 Nonmagnetic, Flame, Acids and Rust Resisting Steel

Temperature	Tensile Strength lbs. per sq. in.	Elongation in 2 inches per cent	Reduction of area per cent
1292°F. (700°C.)	71,470	20	24.7
1472°F. (800°C.)	44,900	28.5	62.8
1760°F. (960°C.)	21,395	37.5	82.4

Tensile Strength of Carbon Steel At High Temperatures

0.76 C, 0.49 Mn, 0.174 Si, 0.016 P, 0.014 S

Temperature	Tensile Strength lbs. per sq. in.	Elongation in 2 inches per cent	Reduction of area per cent
650°C.	45,100	18.2	45.2
800°C.	10,725		100
Room Temp.	131,000	12.5	20.6

Tensile Strength After Being Heated For One Hour at 2200-2350 Degrees Fahr.

482-8 ¾″ sq. hammered bar. Cooled in air.

2200°F. lbs. per sq. in.		2350°F. lbs. per sq. in.
51,960	Yield Point	53,900
93,730	Ultimate Strength	99,240
31.5%	Elongation	43.5%
27.7%	Reduction	43.6%

These yield points were taken with dividers. Strain gauge not used.

Compression and Torsion Values, etc., on 0.038-Inch Sheets and Bars of Nonmagnetic, Flame, Acids and Rust Resisting Steel

	Tension Bar	Tension Sheet*	Compression	Shear	Torsion	Impact	Hardness**	Ductility test
Elastic limit Lb. sq. in	63,660	152,590	81,610	....	52,150	...	...	.....
Yield point Lb. sq. in.	....	....	....	....	.....	...	...	.....
Ult. strength...	122,560	203,150	130,300	82.420	Mod. of Rupture 110,560	...	...	.....
Elongation % in 2 in.	29.3	26.7	....	....	.....	...	...	.....
Elongation % in 4 in.	....	20.9	....	....	.....	...	...	.....
Reduction of area, %	43.8	....	....	....	.....	...	...	.....
Modulus of Elasticity ...	27,170,000	....	....	....	11,713,000	...	...	.....
Ft.-lb. Energy.	....	....	....	....	.....	22.8	...	.....
Scleroscope ...	....	....	....	....	.....	...	48	.....
Brinell	....	....	....	....	.....	...	244	.....
90 deg. reverse bend R-3T...	....	....	....	....	.....	...	...	3 to 4
Min. dia. over which can bend 180 deg. without cracking	....	....	....	....	.....	...	...	4 thicknesses

*Thickness—0.038 in.
**Made on impact specimens.
Note the high physical values obtained in the sheet steel.

Results of Tension Tests at High Temperatures

Temperature	1292°F.	1472°F.	1760°F.
Ult. strength Lb./sq. in.....	52,200	29,715	9,755
Elongation per cent in 2 inches.....	23.0	42	19.5

Ductility Tests on Nonmagnetic, Flame, Acids and Rust Resisting Steel

Cold rolled .029-inch thick 65 scleroscopic hardness Grade No. 3			Treatment Annealed 10 min. at	Cold Rolled .017-inch thick 55 scleroscopic hardness Grade No. 4		
Scleroscopic hardness	Deflection in inches	Total load in lbs. to rupture		Deflection in inches	Total load in lbs. to rupture	Scleroscopic hardness
70	.099	900	500°C.	.139	1500	60
70	.084	500	550	.157	1900	60
68	.041	300	600	.131	1200	60
66	.112	900	650	.154	1500	55
62	.146	1700	700	.150	1400	51
58	.231	3800	750	.192	1800	50
45	.329	6100	800	.247	2200	42
42	.398	8100	850	*	3000	38
40	.374	6900	900	.327	3300	36
40	.371	7200	950	*	3500	35
39	.404	7700	1000	.388	4000	35
37	.403	7000	1050	.409	3900	34
36	.487	8600	1100	.550	4000	34

*Deflection not reported as piece slipped.

Impact Results on Nonmagnetic, Flame, Acids and Rust Resisting Steel. Grade No. 2-2

Size of pieces: 50 x 0 x 10 millimeters
Size of slot: 1 millimeter x 5 millimeters deep.
All samples held for one-half hour at temperatures given.

Treatment		Shore Hardness	Brinell Hardness	Impact ft. lbs.
Natural		47	255	24
600°C.	air	48	241	20

600	oil	50	241	18
700	air	50	255	16
700	oil	50	255	21
800	air	47	241	19
800	oil	50	241	16
900	air	48	241	16
900	oil	47	228	22
1000	air	40	196	39
1000	oil	40	235	27
1100	air	38	196	39
1100	oil	40	192	44
1200	air	31	156	48
1200	oil	30	149	52

Test pieces showing 52-53 foot pounds did not break; they simply bent over.

Specific Gravity of Nonmagnetic, Flame, Acids and Rust Resisting Steel and Monel Metal

Grade No. 3 Rezistal (Sheet)	7.782
Grade No. 4 Rezistal (Sheet)	7.763
Grade No. 4 ¾-inch Hammered Bar: heated to 2200°F. Quenched in oil	8.871
Pure Iron	7.870

Impact Results on Nonmagnetic, Flame, Acids and Rust Resisting Steel. Grade No. 3-10

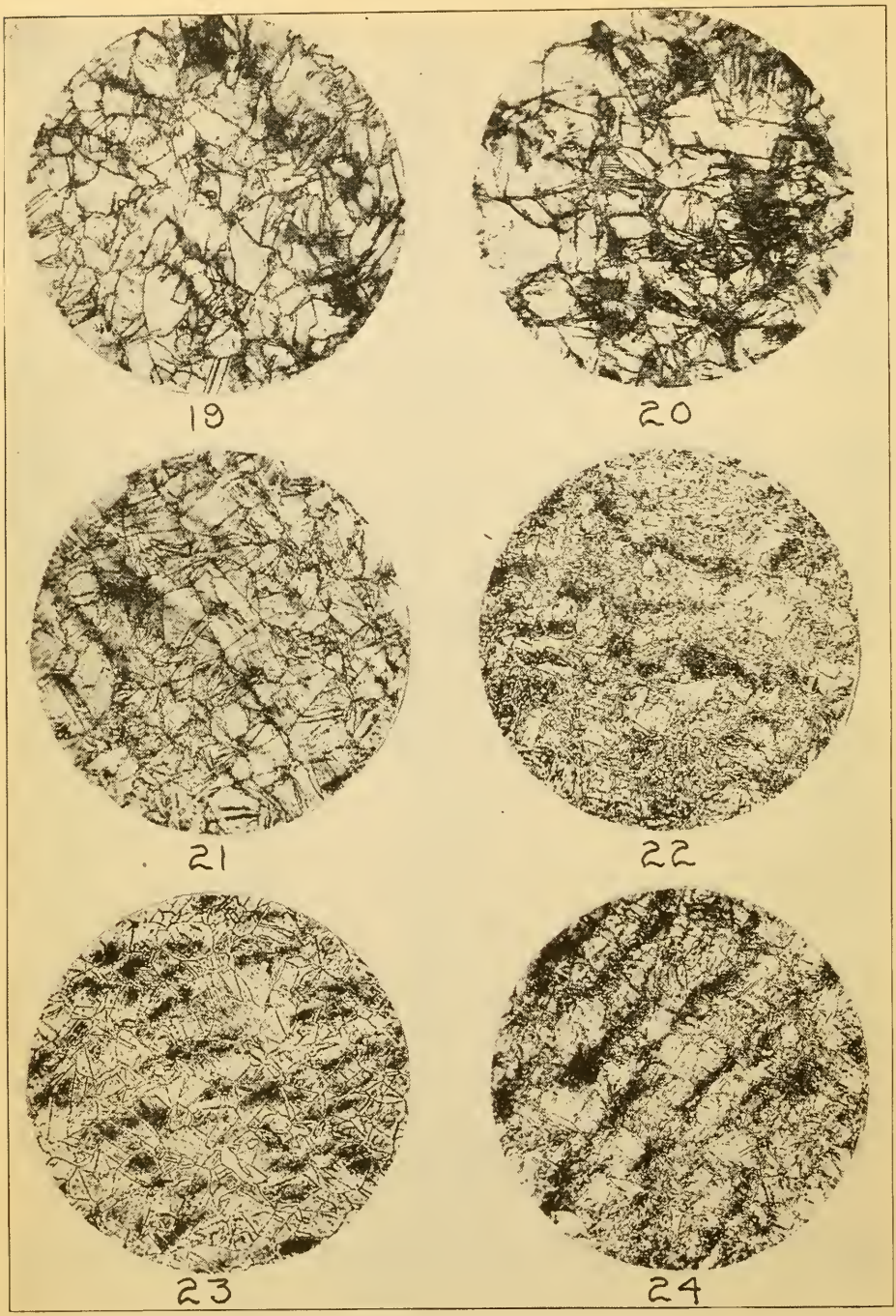
Size of pieces: 50 x 10 x 10 millimeters.
Size of slot: 1 millimeter wide x 5 millimeters deep.
All samples held for one-half hour at temperatures given.

Treatment		Shore Hardness	Brinell Hardness	Impact ft. lbs.
Natural		46	228	18
600°C.	air	46	228	19
600	oil	46	217	25
700	air	46	228	22
700	oil	45	217	20
800	air	45	207	18
800	oil	45	207	22
900	air	43	207	22
900	oil	45	196	22
1000	air	38	163	33
1000	oil	43	179	36
1100	air	34	163	36
1100	oil	33	163	44
1200	air	34	163	51
1200	oil	34	159	53

Test pieces showing 52-53 foot pounds did not break; they simply bent over.

Oxygen and Water Attack Nonmagnetic, Flame, Acids and Rust Resisting Steel, Stainless Steel, Wrought Iron and Monel Metal Immersed in Water With Oxygen Bubbling Through for 24 hours

Grade	Loss per sq. in. exposed surface
No. 3	none
No. 4	none
No. 5	none
Stainless	none
Wrought Iron	7.200 mg. (badly corroded)
Monel Metal	.077 mg.



Transverse sections of microstructure × 300 and hardening at ascending temperatures of grade No. 2-2 air cooled. All specimens were held one hour. Fig. 19—800 degrees Cent. Brinell 262. Fig. 20—850 degrees Cent. Brinell 269. Fig. 21—900 degrees Cent. Brinell 269. Fig. 22—950 degrees Cent. Brinell 241. Fig. 23—1000 degrees Cent. Brinell 241. Fig. 24—1050 degrees Cent. Brinell 241.

Thermal Expansion of Nonmagnetic, Flame, Acids and Rust Resisting Steel

Temperature Range	Average Coefficients of Expansion per Degree Centigrade. Sample No. 3	Sample No. 4
20° to 300°C.	0.0000163	0.0000159
300 " 600	.0000180	.0000179
600 " 900	.0000200	.0000204

The above determinations were made by the Bureau of Standards, Washington, D. C.

The steel when attacked by the oxyacetylene flame requires 20 times as long to melt a hole through it as it does to melt a hole through ordinary steel.

High chromium steel after 30 minutes exposure to oxidizing flame in a gas furnace at a temperature of 2000 degrees Fahr. loses 520.5 milligrams per square inch of exposed surface. The flame resisting steel suffers only a slight staining and a slight gain in weight per square inch after several hours heating at 1900 to 2000 degrees Fahr.

Table III shows resistance to scaling of nonmagnetic, flame, acids and rust resisting steels compared with some other metals and steels. The specimens were ground smooth, weighed, cooled in air and weighed again and loss and gain in weight calculated to milligrams per square inch.

Table III
Nonmagnetic, Flame, Acids and Rust Resisting Steel

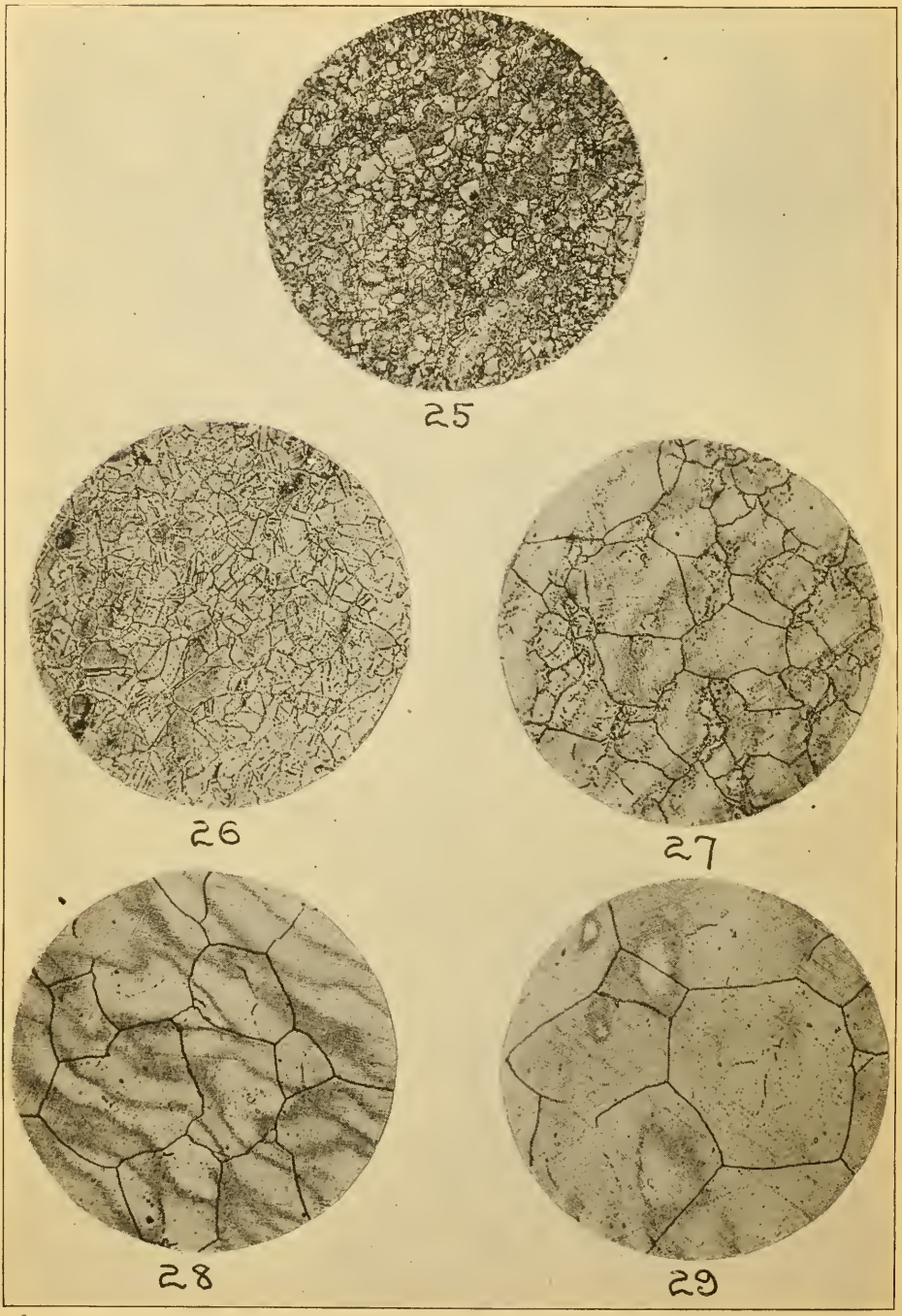
Grade	Loss	Gain
No. 2-2	none	4.8 mg
No. 3-2	none	4.6 mg
No. 4-5	0.3 mg	none
No. 5-1	0000	0000

Other Metals and Steels

Grade	Loss	Gain
Monel Metal	338 mg	no gain
96% Nickel	15 mg	adherent scale
High Cr-Ni Steel	57.1 mg	.....
Grade A Steel	No loss	1.2 mg.
High Cr Steel	520.5	
Copper Steel	967.4	
	1200°C.	90 minutes
Grade	Gain	Loss
No. 3	none	1.5
No. 4	0.5	none
No. 5	none	1.5

It was found that copper would not plate on grades Nos. 3 and 4 on the clean metallic surface either in the neutral or acid solution of copper sulphate at room temperature or at boiling temperature. Copper plates readily on high chromium steel when immersed in either neutral or acid solution of copper sulphate.

These steels will remain for days immersed in ordinary drinking water developing only very slight rust stain. In making such tests, all roll or hammer scale must be removed as the action of water on scale causes rust stains. They show the highest resistance to all fruit acids and staining in general. Paring knives made from grade No. 2 not only never stain, but do not stain the operator's fingers. It must be



Transverse section of microstructure × 300 and hardening at ascending temperatures of grade No. 2-2 air cooled. 1100 degree Cent. Specimen held one hour, remainder five minutes. Fig. 25—1100 degrees Cent. Brinell 223. Fig. 26—1150 degrees Cent. Brinell 217. Fig. 27—1200 degrees Cent. Brinell 179. Fig. 28—1200 degrees Cent. Brinell 174. Fig. 29.—1300 degrees Cent. Brinell 156.

noted, however, that handles for such knives must be wooden or fiber ones as any metal handles made of other than stainless materials might cause staining of one's fingers even though the blade did not stain. No heat treatment is required to render the steel stainless and rust resisting to the highest degree. Progressive rusting is extremely slow.

The following tests were made on grade No. 3 nonmagnetic, flame, acids and rust resisting steel in a small casting as follows: A wash heat of lead was first made in the cast crucible. The molten lead was poured out and the crucible freed from any adhering buttons of lead. It then weighed 1208 grams. It was then refilled with fresh lead and kept at 900 degrees Cent. (1650 degrees Fahr.) for 8 hours in a gas furnace and the lead was again poured out and the crucible weighed 1208.43 grams. No scaling occurred on the outside of the crucible. This would indicate that lead has little or no effect on nonmagnetic, flame, acids and rust resisting steel and neither has the gas flame at this temperature.

Grade No. 3 was also tested by immersing it in sodium cyanide for one hour at 1000 degrees Cent. Also a piece of wrought iron and a piece of copper steel at the same time. The wrought iron and the copper steel lost three times as much weight as the nonmagnetic, flame, acids and rust resisting steel per square inch of immersed surface. The results were as follows:

Grade No. 3 lost 153.6 milligrams per square inch.
Copper steel lost 482.5 milligrams per square inch.
Wrought iron lost 478.1 millgirams per square inch.

Following are the effects of (1) Salt Solution, (2) Quick Lime, (3) Portland Cement, (4) Concentrated Solution of Carbolic Acid, (5) Saturated Solution of Oxalic Acid (6) Hot Asphaltum, (7) Glacial Acetic Acid, (8) Silver Nitrate Solution, (9) Saturated Potash Alum Solution, (10) Hot 20% Caustic Soda Solution, (13) Fresh Butter and Stale Butter, (14) Immersion in Sulphurous Acid.

1. Only slight color tarnish when immersed for 72 hours in saturated salt solution.

2. No change of luster and no loss when imbedded in pasty quick lime solution for 171 hours.

3. Imbedded in pasty portland cement solution for 22 days and allowed to set; luster unchanged.

4. No loss of weight; merest trace of discoloration after 92½ hours in concentrated carbolic acid.

5. Slightly etched in spots after 90 hours in oxalic saturated solution, lost 1.41 milligrams per square inch.

6. Hot asphaltum– Kept in molten asphaltum for one hour; allowed to cool. No loss in weight; slight discoloration suggesting enamel.

7. Glacial acetic acid has no effect in the cold and no discoloring after ninety hours and no discoloration of the glacial acetic acid.

8. This steel when immersed in silver nitrate solution either in the cold or for several hours at 75 degrees Cent. keeps its original luster.

9. After 22 hours immersion in a cold saturated alum solution, this steel shows some slight etched spots. Hot saturated solution attacks the steel slightly more.

10. Polished piece of this steel kept in boiling hot 20 per cent caustic soda solution for 3 hours loses no weight and maintains its original polished surface.

11. Immersion in 30 per cent Sulphuric Acid for one week at Room

Temperatures.

Loss per square inch of exposed surface	
Monel	4.2 mg
Meco	3.6 mg
Grade No. 5	5.7 mg

12. Grades Nos. 3, 4 and 5 are highly resistant to nitric acid up to at least 30 per cent strength, whereas, meco and monel are dissolved by nitric acid.

13. Polished samples of grades Nos. 2, 3, 4 and 5 were put into fresh butter and also into butter that was one month old and quite gassy for 8 days at room temperature. On removing the samples and cleaning the same with gasolene, no change of weight could be detected on a delicate analytical balance and the samples were as highly polished as ever.

Immersion in Sulphurous Acid

14. Grade	1st 2% SO_2 16½ hrs. in cold Loss per sq. in.	2nd 2% SO_2 22 hrs. in cold Loss per sq. in.	3rd 1% SO_2 46 hrs. in cold Loss per sq. in.	4th 1% SO_2 22½ hrs. in cold Loss per sq. in.	5th 2% SO_2 24 hrs. in cold Loss per sq. in.
No. 2	14.7 mg.	19.0 mg.	20.4 mg.	12.2 mg.	
No. 3	7.6 "	0.3 "	10.0 "	0.3 "	12.2 mg.
No. 4	2.3 "	2.4 "	3.3 "	4.0 "	
No. 5	3.6 "	3.2 "	3.4 "	4.1 "	
Monel	0.7 "	1.0 "	1.6 "	1.0 "	
Wrought Iron		1st-37.6 mg. 2nd-39.8 mg. 3rd-88.7 mg.			

Grade No. 3 after first exposure to sulphurous acid solution lost 7.6 milligrams as shown above in Column 1, but on being removed from the first solution and put in fresh sulphurous acid, it was practically unattacked as shown in Column 2, resisting even better than monel metal at this stage. Grade No. 3 took on a dark protective coating which prevented further attack. This curious fact was confirmed by five independent experiments. The fact that the sulphurous acid had no effect on second immersion in fresh acid solution was further proven by the sulphurous acid retaining its strength and showing no cloud of sulphur.

When a sample is attacked, a strong smell of hydrogen sulphide is first noticed followed by an immediate clouding of the liquid with white milk of sulphur. The following equations explain what happens as these tests were made in tightly stoppered bottles to prevent escape of SO_2:

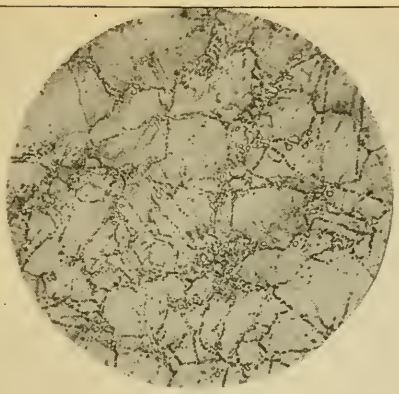
$$(1) \quad SO_2 + 3\,F_e + H_2O = H_2S + 3\,F_eO$$

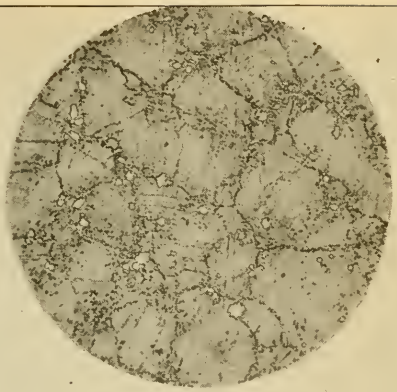
$$(2) \quad SO_2 + 2\,H_2S = 2H_2O + 3S$$

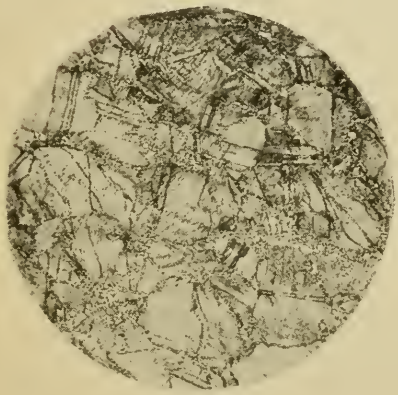
The following table shows resistance to scaling of nonmagnetic, flame, acids and rust resisting steel compared with some other metals and steels. The specimens were ground smooth; weighed and measured; then heated to 1150 degrees Cent. for ½ hour in a gas furnace; cooled in air; and weighed again and loss and gain in weight calculated to milligrams per square inch.

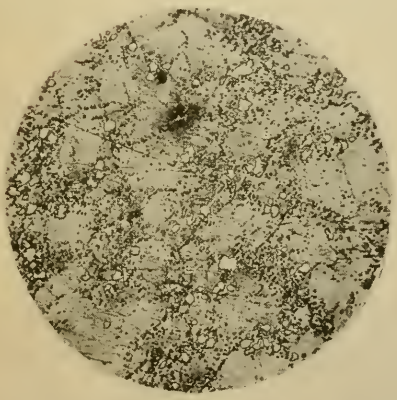
Nonmagnetic, Flame, Acids and Rust Resisting Steel

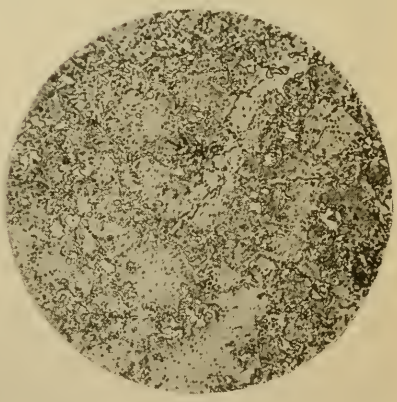
Grade	Loss	Gain
No. 2-2	none	4.8 mg
No. 3-2	none	4.6 mg
No. 4-5	.3 mg	none
No. 5-1	0000	0000



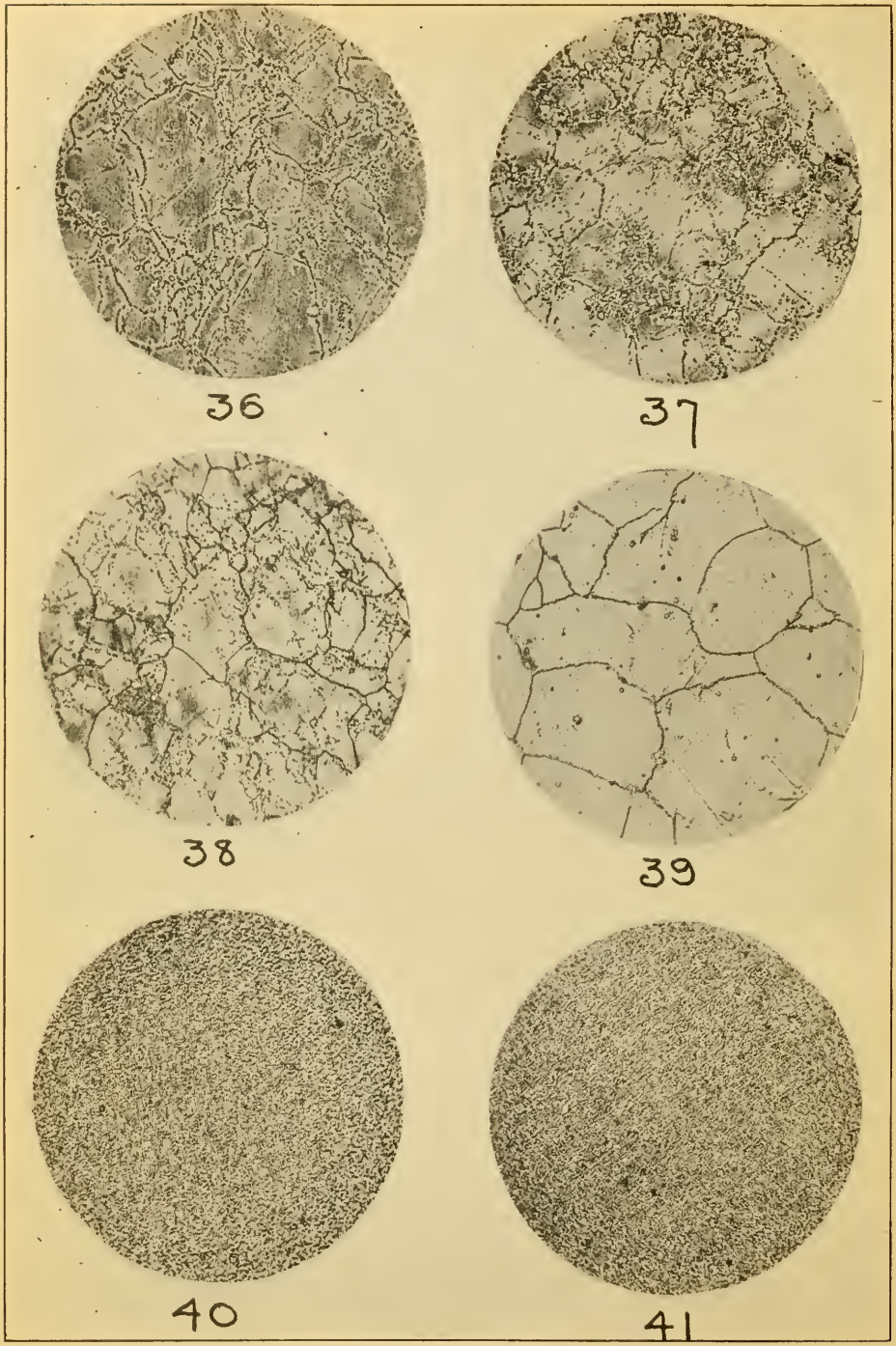








Transverse sections of microstructure × 300 and hardening at ascending temperatures of grade No. 3-2 air cooled. Specimens up to and including 750 degrees Cent held two hours, above 750 degrees Cent. held one hour. Fig. 30—550 degrees Cent. Brinell 228. Fig. 31—650 degrees Cent. Brinell 255. Fig. 32—700 degrees Cent. Brinell 241. Fig. 33—750 degrees Cent. Brinell 235. Fig. 34—800 degrees Cent. Brinell 235. Fig. 35—950 degrees Cent. Brinell 217.



Transverse sections of microstructure × 300 and hardening at ascending temperatures of grade No. 3-2 air cooled. 1050 degrees Cent. specimen held one hour, remainder including 1300 degrees Cent. held five minutes. Fig. 36—1050 degrees Cent. Brinell 207. Fig. 37—1150 degrees Cent. Brinell 207. Fig. 38—1200 degrees Cent. Brinell 179. Fig. 39—1300 degrees Cent. Brinell 159. Fig. 40—High chromium steel, 650 degrees Cent. Held two hours. Shore 45. Fig. 41—High chromium steel. 800 degrees Cent. Held one hour. Shore 53.

Other Metals and Steels

Grade	Loss	Gain
Monel Metal	338 mg	no gain
95% Nickel	15 mg	adherent scale
High Cr-Ni Steel	57.1 mg	
Grade A Steel	no loss	1.2 mg
High Cr Steel	520.5 mg	
Copper Steel	967.4 mg	

This steel scales very little at 1800 degrees Fahr. even after long periods of heating.

For machining, this steel should be heated at about 800-850 degrees Cent. and held there until thoroughly heated and then allowed to cool down to room temperature before it is taken out of the furnace. After annealing at 850 degrees Cent. and cooling in the furnace to room temperatures, the steel can be machined, drilled or milled with high speed tools. For cutting off to length, a friction saw running at high speed or a thin carborundum wheel can be used. The best method found so far is to use a thin metal slitting saw of regular standard high speed steel. This steel cannot be cut successfully with an ordinary hack saw.

Steel should be brought to a temperature of 1150-1200 degrees Cent. and held at this temperature for one half hour in thicker sizes. In thin sheets, it need not be held more than 5 or 10 minutes; then turned over and held 10 minutes more. It should then show a scleroscope hardness of 30.

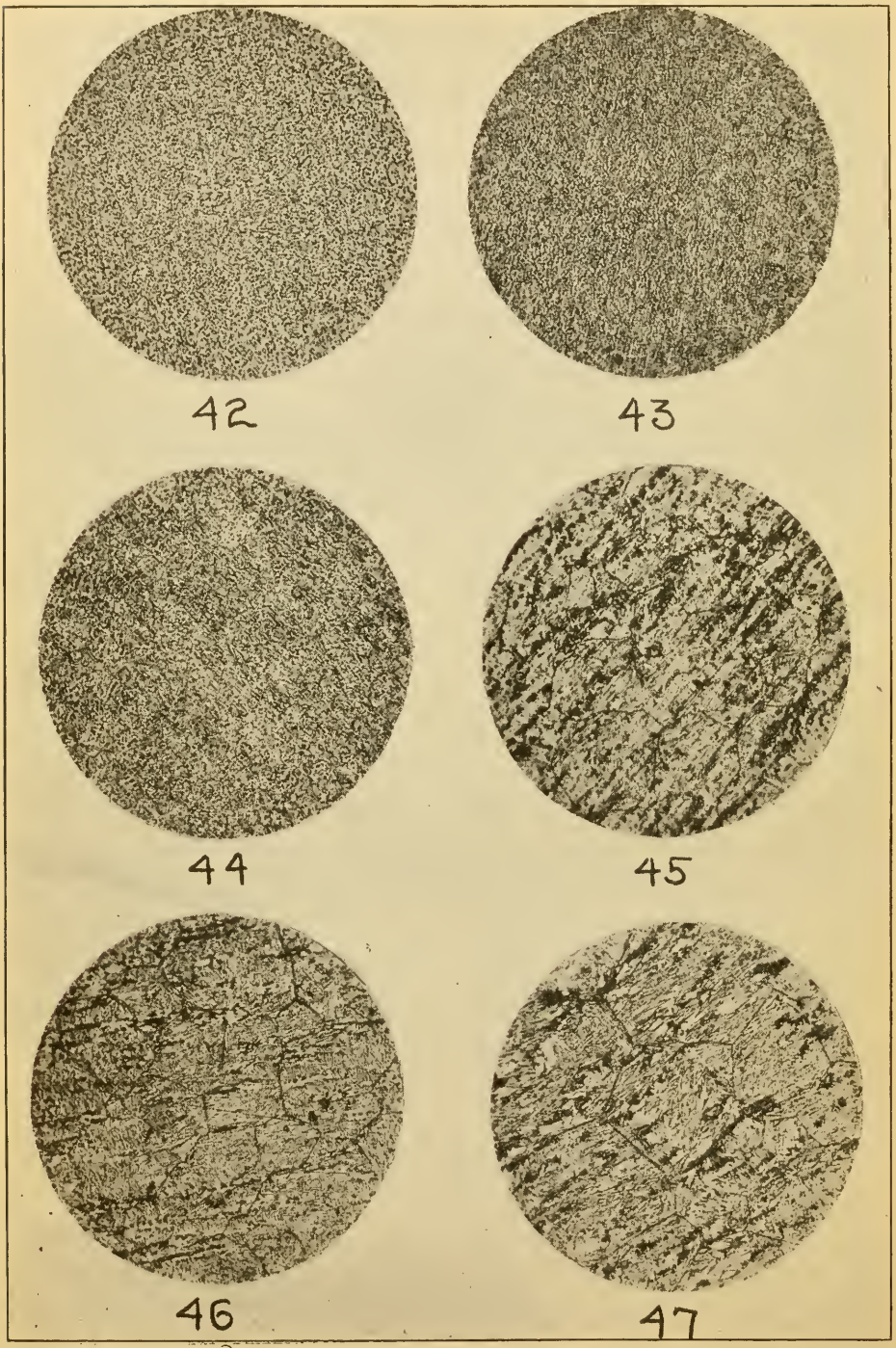
This steel can be welded best with the oxyacetylene flame using a strip of the same material to fuse the edges together and a suitable flux. The sand blasted or pickled sheets should weld the best as if scale be still on the sheets, it may interfere seriously with the welding. This material gives excellent welds on cast iron by the electrical welding method.

Nonmagnetic, Flame, Acids and Rust Resisting Steel and Stainless Steel in 1/1000 Mercuric Chloride Solution

Polished sheet	Loss after 120 hours cold	Loss after ½ hour boiling	Appearance of sample at finish	Solution at finish
Grade No. 3.....	0.45 mg.	2.1 mg.	Bright; lustrous	Small white deposit at bottom of solution
Grade No. 4.....	3.1 mg.		Bright; lustrous; very slight stain	Slight brown deposit at bottom of solution
Hardened stainless..	4.3 mg.	2.5 mg.	Bright; lustrous	Brown deposit at bottom of solution

Nonmagnetic, Flame, Acids and Rust Resisting Steel and Stainless Steel in Lactic Acid Attack

Grade	Time	Reagent	Loss per sq. in. in exposed surface	Effect
No. 6	24 hrs.	0.2% Lactic	none	No noticeable attack
No. 4	"	"	none	No noticeable attack
No. 3	"	"	0.4 mg.	Solution faintly yellow
No. 6	24 hrs.	1% Lactic	0.1 mg.	No noticeable attack.
No. 4	"	"	0.86 "	Sample became tarnished; decidedly yellow solution.
No. 3	"	"	1.4 "	More pronounced tarnish than H-46; deep yellow sol.



Transverse sections of microstructure × 300 and hardening at ascending temperatures of high chromium steel air cooled. Specimens including 1050 degrees Cent. held one hour, remainder five minutes. Fig. 42—900 degrees Cent. Shore 72. Fig. 43—1050 degrees Cent. Shore 80. Fig. 44—1150 degrees Cent. Shore 85. Fig. 45—1200 degrees Cent. Shore 76. Fig. 46—1250 degrees Cent. Shore 78. Fig. 47—1300 degrees Cent. Shore 78.

No. 6	24 hrs.	5% Lactic	none	
No. 4	"	"	0.85 mg.	
No. 3	"	"	1.02 "	
No. 6	24 hrs.	20% Lactic	none	
No. 4	"	"	0.94 mg.	
No. 3	"	"	1.46 "	
Regular Stainless unhardened	"	"	51.85 "	Developed dark coating that rubbed off in washing; leaving clean etched surface; green solution.

Nonmagnetic, Flame, Acids and Rust Resisting Steel Attack by Water Through Which a Stream of Carbon Dioxide Is Passing

Loss in milligrams per square inch exposed surface 41 hours at 20° C.		Appearance of sample at finish.	Appearance of liquid at finish.
482-8	No loss	Absolutely no signs of tarnish or attack lustrous.	Water white, clear.
500-1	0.054 mg.	Bright and lustrous, no discernable attack.	Faint, yellowish tinge.
Monel	3.01 mg.	A loose coating of brown and yellowish green rust metal smoothly etched.	Yellowish-green deposit settled out on standing. Sample showed signs of attack after 10 minutes immersion.
0.50 carbon Plain steel	7.18 mg.	Loose yellow rust in considerable quantity. Sample attacked quickly after immersion. Metal etched, dark gray color.	Yellow rust settled out bulky precipitate.

Nonmagnetic, Flame, Acids and Rust Resisting Steel and Monel Metal in Gasoline

Grade	Reagent	Time	Loss per sq in. exposed sur.	Effect on sample	Cleaned with warm water and soap
No. 4	Gasoline	30 days	0.63 mg.	Slight brown spot on surface.	Very slight etching.
No. 3	"	" "	0.73 "	Slight brown spot on surface.	Very slight etching.
Monel	"	" "	4.08 "	Tar-like coating over entire surface.	Luster dulled.

Tensile Strength of Nonmagnetic, Flame, Acids and Rust Resisting Wire, Grade No. 4 in Cold Drawn Condition

Size	Area	Breaking load	Lbs. per sq. in.
	Cold Drawn Condition		
.148	.0172	2650	154,000
.125	.01227	2020	164,500
.064	.003217	560	175,000
.054	.0029	530	182,600
.047	.001734	375	216,800
.041	.00132	350	265,000
.032	.0008	180	225,000
	Annealed Condition		
148	.0172	2020	117,500
.125	.01227	1375	112,000
.064	.003217	475	148,500
.054	.0029	300	103,500
.047	.001734	240	138,500
.040	.00132	255	192,800
.032	.0008	160	200,000

Suggested Uses For Nonmagnetic, Flame, Acids and Rust Resisting Steel

Boiler tubes—either water or fire tubes.
*Rails, racks and trays where ordinary steels scale heavily at temperatures ranging from 1600 to 1800 degrees Fahr. in enameling furnaces.
*Valves and parts for internal combustion engines to resist high temperatures together with corrosive fumes.
*Cooking utensils such as pots, skillets, etc., that are to be kept bright; spatulas, paper cutters, trays in gas ranges that burn and rust readily when made of ordinary steel.
*Vault plates and hinges that are to resist attack of oxyacetylene flame and burglars' saws and drills.
Boxes for safe deposit vaults.
Planes for aircraft being light and having great strength and ductility in thin sections for highly stressed parts.
Oil burners.
Tips for oxyacetylene cutting torches.
Roof gutters and conductors.
*Annealing boxes; case hardening boxes.
*Flue dampers in furnace stacks.
Check valves and valves of all kinds in steam lines.
Pipes and tanks for carrying commercial sulphuric and nitric acids at atmospheric temperatures.
Pipes for corrosive mine waters.
Pickling vats and rods for same.
Nails for resisting acids.
*Rivet heating furnaces.
Hotel and kitchen cutlery nonbreakable super-stainless that can be easily sharpened requiring no heat treatment by the cutlery manufacturer.
Saw tooth bread and cake cutters.
Rust resisting tapes.
*For instruments in all places where a steel is desired that is of the lowest magnetic susceptibility.
*Containers for acetic acid and other corrosive organic acids.
Hot plates in laboratories being highly resistant to acid and heat attack.
Long life muffles for heat treating furnaces that do not operate above 2000 degrees Fahr. or use low pressure air for shorter life period at 2100 degrees Fahr.
Hoods and running boards for automobiles.
Turbine blades.
Fertilizer pans.
Tubes for annealing needles.
Dies for die casting.
*Shafts for motor boats to resist sea-water.
Pyrometer protection tubes.
Valves and valve seats for steam traps.
*Paring knives for fruits, potatoes, etc.—no staining of either steel or the operator's fingers.
Polished surface of flat irons.
Golf sticks.

Hooks and wires for suspending parts to be hardened in high temperature hardening such as high speed steel.
Fuel feeder sheet steel.
Tanners tanks, perforated bottoms.
*Gun barrels—rifle and shot gun barrels—stainless, nonrusting and noncorroding from ammunition.
Art Vases and statuettes.
Spoons—Stainless spoons will not tarnish as silver does.
Tunnels for manufacture of lamp black.
Spokes—Wire spokes for automobiles, motorcycles, bicycles, etc.
Burial caskets—Highest resistance to rusting.
*Cast lead pots—no scaling loss.
*Cast cyanide pots.
Cast annealing boxes.
Cast parts of rivet heating furnaces. (castings)
Mine water pumps and machinery being highly resistant to cold sulphuric acid.
Castings in general for resistance to acetic, sulphuric, and nitric acids at ordinary temperatures and to scale loss at temperatures up to 2000 degrees Fahr. and rusting.
*Wire— Rust resisting wire for umbrellas.
*Wire— of high electrical resistance; 560 ohms to mil foot.
Wire— of great toughness and rust resistance for mine cables and cables for incline planes.
Runners for ice boats.
Punties for polishing glass.
Rods for skimming brass.
*Hardening trays for steel stamps; splendid reports—no warping.
Wire to stand red heat continuously for shoe machinery work—No. 3 stands good; No. 4 better.

The uses marked with an asterisk (*) have already been tried and found to be successful.

FACTORS GOVERNING THE PRODUCTION OF HEATED PRODUCTS

By J. A. Brown*

(A Paper Presented at the Philadelphia Convention)

In the production of a heated product, particularly that in which heat treatment is a part, it is necessary to select that form of equipment and fuel adapted to the individual plant conditions, which when properly combined and operated will produce the result sought. In general terms this may be summed up as producing a finished product of given quality at minimum cost.

To produce this result the principal factors to be considered may be grouped under three principal heads; the first is the quality of finished product; the second the facilities available or required to produce this product, these in turn determining the cost of the finished product.

The quality of the product depends upon the raw material and upon the heat treatment it receives. The term raw material is here used in its economic sense in that the finished product of one group of producers becomes the raw material of the following group. Each step requires a definite combina

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tion of material, process and skilled effort for its transformation. Raw material, before heat treatment, includes material more or less fabricated, having been cast, rolled, or forged at working temperatures considered suitable for these operations but with, perhaps, indifferent or little attention given to the resulting structure or condition. The chemical analysis probably checks within the limits required by the specifications, but the physical properties and structure may indicate considerable lack of uniformity in the material submitted to heat treatment. This condition merits far more attention than it has received, as every heat treater is familiar with many instances in which the after treatment is expected to restore those properties that have been sacrificed in working the raw material.

Heat treatment is commonly understood to consist of a definite succession of heating and cooling operations and the heat treatment as a process is good or bad to the extent that these operations are made definite and that the variables involved may be controlled. Control requires the duplication of condition and results and demands a high degree of standardization. Thermally, heat treatment simply covers an interchange of heat, and the thermal action is between two substances, one giving up heat and the other receiving it. A hotter fluid, flame or substance surrounds or plays on a cooler substance or object and, due to the difference in temperature, the cooler object becomes heated and the surrounding substance loses heat. The manner in which the heat is applied determines the uniformity with which the heat is absorbed.

In order that the change in the structural composition of the metal may be unobstructed, it is a fundamental requirement that the heating and the cooling should be uniform. Uniformity in heating produces the required structure in the least time with the least expenditure of heat energy, while uniformity in cooling fixes the final structural composition.

For every piece subjected to heat treatment this question must be answered: "What temperature is required?" and a workable answer depends upon data of various natures resulting from actual investigation. Fundamentally, it is a question for the metallurgist to answer correctly and fix the degree of heat required in a given operation. In a physical sense, the temperature variation in and around the piece being heated and the degree of accuracy with which this temperature variation may be controlled determines the uniformity of heating.

Equally important is the time in which the material is heated or held at temperature before cooling. Time depends not only on the mass of the material but on the surface exposed. The relation of mass and surface is a function of the shape and it is readily appreciated that an irregular shape with unequal metal thickness offers more difficulties than a simple shape of uniform thickness. Heat transfer can only take place where a temperature difference exists. The greater the temperature difference, the more rapid the flow. As the difference becomes less the flow decreases until equilibrium or saturation is reached. Obviously the temperature in the heating zone should not be higher than the temperature required for the operation or process, though it is evident that a longer time will be required to heat. In forge shop practice high temperature and incomplete saturation are responsible for the socalled wash heats, where the surface of the metal may be dripping and yet a hard core will be found in working under hammer or press.

The atmosphere in the furnace has a very direct effect on the quality of finished product. This atmosphere or condition in the furnace may result

from the fuel used or from the conditions under which the fuel is burned. Soot and ash result from the physical condition under which a fuel is used, soot indicating unconsumed fuel. Ash is frequently a troublesome feature, when coal is used in powdered form. Some operations require a clean fuel and we find anthracite in use in the soft coal districts and natural gas in the ceramic and glass industries of the Middle West.

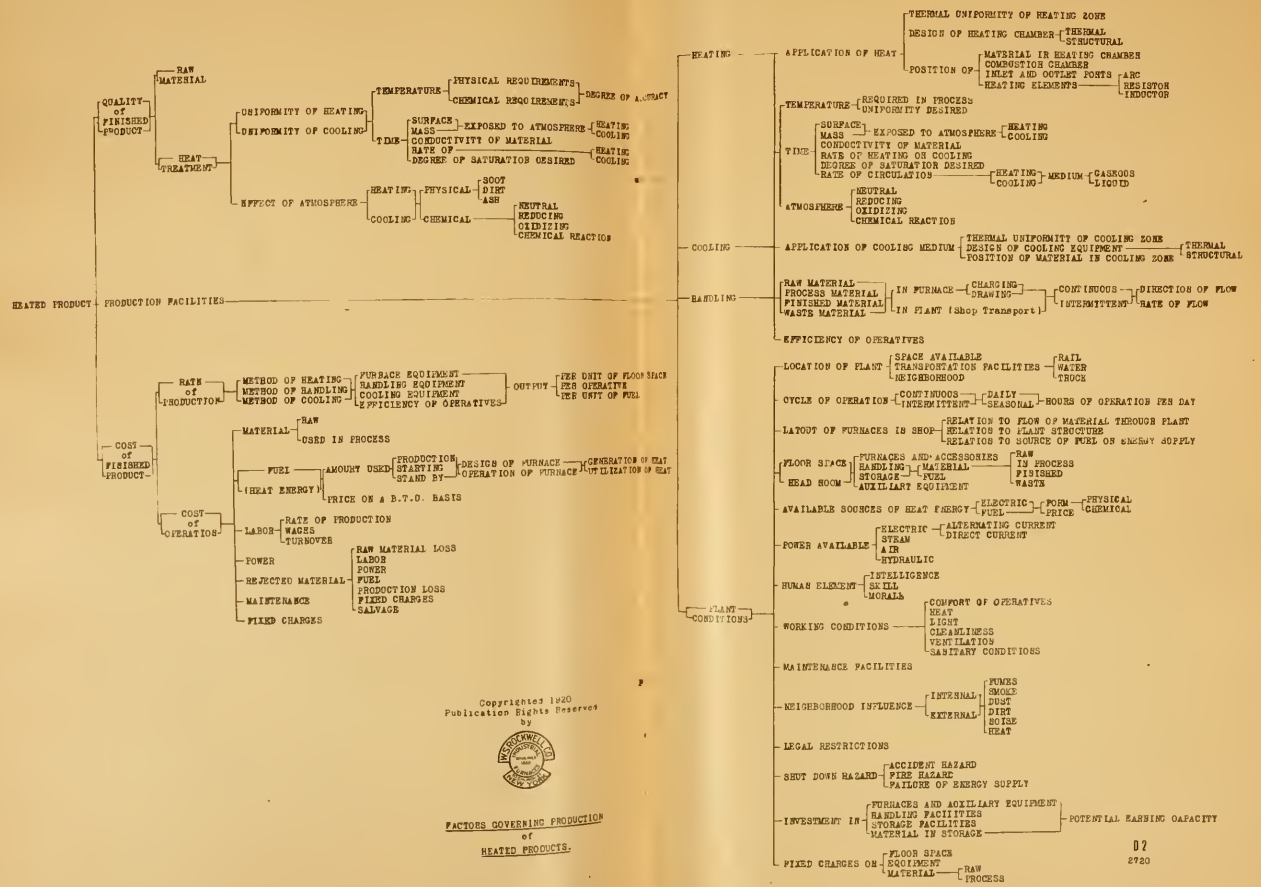
At times it may be necessary to protect the work from contact with the furnace gases and in this case muffles of refractory materials are employed. The atmosphere within the muffle may be oxidizing or reducing, though usually oxidizing. Enameling, glazing and similar operations are conducted in this way. Vitreous enamels may be made in the electric resistance furnace but in the arc furnace, the gases from the electrodes are very liable to have a reducing effect upon the oxides in the enamel. Special atmospheres to control a chemical reaction are obtained by the use of muffles filled with gas or superheated steam. Atmosphere is not due to any particular fuel or type of furnace, but depends entirely upon the air supply for a given fuel. Where the air supply is less than that theoretically required for combustion, so that the gases in the heating chamber carry no free air but contain a small percentage of fuel gas, a reducing atmosphere is maintained.

Production facilities must be provided with regard to the manufacturing requirements and in harmony with the plant conditions. For a given quality of output, the heating, cooling and handling methods must meet the requirements of the process.

The application of heat is not an abstract question or one to be determined from a discussion of fuel values or combustion, nor is the heat balance a real test of the equipment. The application of heat is essentially one of dynamics for heat flow and the thermal condition around a mass to be heated is not determined by the temperature indication at one or more points in the furnace. The stress that has been laid on uniformity of temperature in the chamber leads to false conclusions inasmuch as the temperature at any particular point represents what might be termed a static condition, while fundamentally we are concerned with the transfer of energy and not the indication of temperature. The real condition governing the design of the heating chamber is that the heat be uniformly applied to and absorbed by the work.

Absorption of heat varies with the position of the material in the heating chamber, the location of the combustion chamber in relation to the heating chamber, or, in electric furnaces, to the position of the heating element in relation to the charge. Many electrically-heated furnaces, particularly those of the semi-arc or resistance type, function in the same way as a fuel-fired furnace. The product or material in the furnace is heated by conduction and radiation. The electric energy is used to heat the resistor, which in turn transmits the heat to the product by the atmosphere or by radiation. The laws governing the movement of the gases in the heating chamber are the same with either form of energy. With electricity as with fuels, the uniformity of heat throughout the chamber and uniform heating in the chamber do not necessarily go together, as the result is a function of design and operation and not something inherent in the energy itself. It may be said, however, that electric energy in some form of special equipment can accomplish results not possible with any form of fuel-fired furnace.

In one sense there is no absolute uniformity in the temperature of the gases in the heating chamber. From the time combustion is completed and



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until the gases leave the heating chamber, they are giving up heat, and at the same time, decreasing in temperature. This condition determines the position and design of inlet and outlet ports. Hot gases rise and must therefore be pulled down; cold gases fall and must therefore be pushed up. The high velocity of gases, due to a temperature difference, is not generally appreciated. It is evident that the heating conditions, when the chamber is empty, are very different from those existing when the chamber is full. In many cases the chamber is so overloaded that the flow of heat becomes essentially that through a series of flues, and consequently the placing of the charge should follow the fundamental requirement that a hot gas when cooling should go down; a cold gas when heating should go up, and this condition of flow be fixed by the location of the ports.

Most malleable iron annealing furnaces are packed too solidly and often times the rejections would be materially reduced by the use of a smaller charge placed with more open space between the saggers. In some periodic kiln operations, a virtue is made of necessity, due to improper application of heat, for instance, abrasive wheels are graded by their degree of burn due to their position in the kiln. The same defect in placing the charge is often observed in carbonizing furnaces and is aggravated by the relatively short time required for the carbonizing operation. There is no excuse for this practice in open chamber heating and from a pile of pieces in one charge; it is often possible to pick out two or three distinct degrees of heat.

The same considerations that govern absorption of heat by the work apply with equal force to the cooling or quenching of the work. Where the work is cooled by quenching the action may be much more drastic in its effect on the steel and therefore requires more refinement in the details of handling. Heat gives the structure, cooling fixes it. Heating should be slow and may be prolonged with less injury than where the heating is too fast. There is not the same flexibility in the cooling operation which must be performed with more precision in point of time. Heating and cooling may be more or less automatic through the mechanical handling of the work, and the same consideration of the effect of surface and mass upon the time and temperature should be given to the cooling or quenching process that is given to the heating.

As the size of the work increases, the difficulties of heat treating largely are those of handling the material. The mechanical handling of hot material gives rise to quite a different set of conditions to those met in handling cold material. Each definite range of temperature requires the development of a satisfactory method of handling. The methods of handling molten steel have been practically standardized for each particular process. The making of brass castings follows a common procedure. There are no standard methods in handling a heat treated product as each instance must be dealt with on the basis of fuel and furnace adapted to the work. In many ways, the difficulties of handling the work are lessened when the transfer is made on a horizontal plane with little or no change in the working level during the operation. Furnaces used in connection with sheet rolling mills often have the hearth line at the same height as the roll. Forge furnaces have their hearth line at the level of the hammer or press dies.

Plant conditions not only affect the quality of the output but may materially affect the cost of a finished product and should be considered in detail as part of the production facilities.

In the location of a plant the cost of land is seldom a determining factor. Contour may be taken advantage of for certain operations. Level ground or hillside may have particular features desired for certain processes. A difference in elevation may permit the conveying of material by gravity or aid the disposal of waste. Low undrained spots may be used as a dump for waste material.

The space available fixes the type of construction and may lead to a one-story building or to a concentration in a high story building. In a high story building the flow of product may be vertical, from top down, instead of horizontal. In the manufacture of many lines of small metal parts material received at the ground floor is raised to the upper floor and then progressively descends while being processed until it is finally packed for shipment at the same level on which it was received.

Transportation is of importance and vitally so at the present time. While freight rates on different classes of commodities have a marked influence, there must be a general balance between raw material and the market for the finished product, with power, fuel and other items shifting the fulcrum of this balance. Nearness to source of raw material and nearness to final markets should be considered. Nearness to special labor markets have settled special trades in certain localities, for instance, the brass industry in the Naugatuck Valley. Fuel or power may be determining factors as the cheap power development at Niagara, cheap fuel at Pittsburgh, and water power in New England. In general, rail transportation is preferred to water for nearly all purposes, as the latter is often inoperative for part of the year.

The general tendency is for a small plant to locate in a city or suburbs. In a large city, while the labor supply may be plentiful, it is apt to be inferior in quality and unsteady. At the same time such location usually offers the advantages of fire and police protection, water supply and sewerage. A location between two near cities is affected by the high labor turnover due to the general floating or drifting of labor from one city to the other. In general the tendency as the size of the plant increases is away from the city leading, in some cases, to an isolated industrial community.

The cycle of manufacturing operations may require that two or more departments be adjacent or in definite relation to each other, or it may require one or more passages of the work through one of the departments, as an annealing operation following successive machine operations. Layout requirements should, as far as possible, be in harmony with those conditions tending to reduce fire and accident hazard. Where possible operation should be continuous rather than intermittent and this is determined by the size of the furnace as well as by the process and the temperature required. The operation may be continuous, as that of a blast furnace, or an intermittent operation may be carried on continuously as in the open-hearth furnace or an intermittent operation as malleable iron annealing or burning ceramic ware where the charging, heating and cooling cycle may extend over a period of several days. None of these operations would be practicable on an eight-hour basis with a shutdown at night.

Since the furnace operation is but one in the sequence of the manufacturing operations, it follows that the furnace should be located in its proper point in the order of operations, although in general this sequence is due to the economics of handling rather than the particular geographical

position, and the internal transportation system of a plant determines the relative position. The question of location is usually one of compromise or a balancing of alternatives. Work is brought to and taken from the furnace. Its form may be the same or different as in a melting furnace or a cupola where solid raw material is charged and the charge in a liquid or molten state is transferred to another point.

Fuel is brought to the furnace and, in the case of solid fuel, ash or refuse is removed. Just how far it is desirable to locate the fuel supply in relation to the furnace, depends on the character of the fuel. Fuel oil, from its nature, is readily and cheaply distributed through a plant at small cost for pumps and pipe lines. Gas has similar advantages in distribution. Cold washed producer gas may be piped through a plant as required. Hot producer gas must be used comparatively near the generator. 'Energy in the form of electric current is very flexibly distributed. With solid fuel the cost of handling is large compared with the cost of the fuel. This tends to place the furnace in close proximity to the fuel supply.

In the grouping of furnaces, a single process leads to the simplest and most compact grouping. With several processes underway at the same time, an entirely different arrangement of floor space, different methods of handling and even different fuels may be required. The facilities for handling the fuel may require as much space as the furnace and the auxiliary equipment becomes a large item in the required floor space. An electric heating furnace may require a transformer that takes up more space than the furnace.

In general the sources of heat energy available for industrial purposes are those fuels provided by nature; coal, wood, oil and natural gas, or electric energy from the above fuels or from water power. Coal may be used in its raw state· it may be powdered, which changes its physical form but not its chemical form, or it may be gasified, changing its physical as well as its chemical form. Depending upon the method of gasification, coal is the basis of gases having widely different qualities ranging from producer gas with a low B. t. u. content per cubic foot through various mixtures of coal gas, producer gas or water gas under the general name of fuel gas. Coal gas in general has the highest B.t.u. value per cubic foot while blue water gas, intermediate in value between producer gas and coal gas, gives a higher temperature.

A fuel to be commercially available must have a form, value and price that will permit its use in the particular form most suitable for the purposes desired. The unit cost of gaseous fuel is much greater than that of the solid fuel from which it is obtained but due to its form value, the gaseous form permits a reduction in the net fuel cost per unit of product. Fuel is here considered simply a source of latent heat energy without taking account of its commodity value. The principles governing the application of heat and the factors entering into the result are the same in electric heating as with other fuel, and while the flow of electric energy is readily controlled, it must be realized that this does not imply the same degree of control in the application of the heat produced.

The power available may influence the type of furnace and the method of handling the work through the furnace but in general the question of power concerns principally the operation of auxiliaries and continuous or intermittent demands for power will influence the choice. Electric and

steam power are well adapted to continuous operation. Steam power, due to condensation, is not well adapted to an intermittent demand. Electric, air and hydraulic power are adapted to intermittent operation where the energy may be stored during certain parts of an operating cycle. Electric power is gradually superseding air and hydraulic power in steel mill practice.

In considering the human element, intelligence may be purchased but without skill has potential value only; skill may be required but without intelligence will accomplish indifferent results. Morale must be developed; labor has in a large measure lost that sense of fidelity and loyalty to the ideals of a trade that forms a basis morale. This question must be solved in each plant depending upon the type of organization, the distribution of responsibility and the sequence of authority are large factors in determining the most effective form of co-operation.

Recent and to some extent present conditions show that while the working conditions within the plant may be of the best, if the workman has no suitable place to live, his value as a producer is greatly diminished and the type of workman is directly reflected by his home surroundings. The cheap lodging house or bunk house under unsanitary conditions reduces the type of labor to that of the floater, unskilled, of low intelligence and often a menace morally as well as physically to the community. Sanitary conditions mean health, self-respect and increase in the morale. These conditions have been studied in connection with the "safety first" movement leading to a more technical study of occupational disability.

The following conditions are quite common in connection with furnace installations; high temperatures, humidity, noise, vibration, insufficient illumination, excessively bright or harmful industrial lights, vitiated fume or dust laden air. While heat is fundamentally a part of the subject considered, every effort should be made to lessen its ill effects and to prevent its radiation. To some extent this may be attained by the use of heavy, well-insulated furnace construction, water-cooled or insulated doors, protective shields or screens and a natural circulation of air due to locating the furnaces away from walls and by placing them in the center of the building. Ventilation may be improved by a forced air blast directed from the walls and windows to the center of the building.

In connection with the application of heat in industrial furnaces, maintenance of structure and production requires considerable study. In order to reduce the shutdown or time that an appliance is out of service, it is desirable to use standardized units as far as possible, to keep sufficient spare parts on hand and to use standard material in construction. Simplicity of construction is the first requisite and in furnace work the use of standard brick shapes and the avoidance of special tile should be considered. The value of standardization is not fully appreciated. For instance, a consulting engineer bought for export one each of three different makes of melting furnace.

Fume, smoke, dust, dirt, etc., have a direct injurious effect in causing discomfort to the operator, decreasing the productive ability, and resulting in the general lowering of the resistance to disease. When these elements are ejected outside the plant, the surrounding neighborhood suffers injury. Fume and dust from certain chemical and metallurgical operations, smoke from furnaces or boiler plants, noise from hammer shop, have an injurious effect on the neighborhood and eventually affect its character, sometimes

leading to a warefare in which the neighborhood or industry is a victim, the neighborhood is lowered in character or the plant moves.

Some of the conditions outlined above are controlled by restrictions. These restrictions may be legal as by municipal ordinance, state or federal enactment; or the result of a mutual contractural relationship as that with insurance companies; or the restrictions may be moral as imposed by the general civic sense or industrial conscience. Legal restrictions are most direct in their deterrent effect providing, as they do, a penalty for non-observance, at the same time they are very apt to be below the actual needs as indicated by public policy.

Accident and fire hazards may be minimized by the observance of accepted principles of safety engineering and may be covered in part by insurance governing the hazard peculiar to the use of certain forms of heat energy, such as the method of storage, the quantity stored, method of handling, and the way in which it is used. One of the older principles of fire protection was that fires cannot be prevented but they can be controlled and stopped; the newer idea is not only fire protection but more insistently fire prevention.

Failure of energy supply apart from accident, is due largely to transportation troubles and to labor troubles which may interrupt either production or transportation. Such interruption may be reasonably guarded against by providing proper storage. In some cases the user must provide for these contingencies while in others the producer does so by providing local storage. The exhaustion of one source of fuel may require a change to another fuel, or conservation may demand a seasonal distribution or restriction in favor of certain classes of users, as with the natural gas supply in Pittsburgh.

As furnace operations differ widely in the fuel used and in the method of utilizing it, the capital cost or investment in any proposed combination of furnace and fuel should be carefully estimated as it may be found that the cost of furnaces with their auxiliary equipment and handling devices and the cost of fuel storage for any particular fuel does not give the return in earning capacity that another combination of equipment and fuel would give, or when the same floor space is devoted to productive use and the heat energy purchased. The amount of capital which may be tied up in this manner and the real estate occupied as well as the cost of operating a fuel storage plant, not only affects the cost of the fuel used but must be balanced against the potential possibility of utilizing the land and capital as well as a corresponding amount of expense in productive operations. In the same way the fixed charges on floor space, equipment and material must be considered in connection with the investment required and balanced against the potential earning capacity of a different combination of these items.

With a given quality of product and given production facilities, the cost of the finished product will result from the rate of production and the cost of operation. The rate of production will depend upon the output and the hours of operation per day or other unit of time. Output and rate of production will govern the selection of a furnace equipment, the method of heating, the method of handling and the method of cooling. These in turn are influenced by the efficiency of the operatives. There are no fixed standards to determine definitely the form of equipment or fuel to use.

Both must be selected with regard to the manufacturing requirements and the plant conditions. Fuel and equipment should be selected for what it can do under specific conditions.

Output per unit of floor space per operative or per unit of fuel are definite checks on the manufacturing conditions. Cost per unit of fuel or per unit of output is not determinative, and the real question is: What does it cost to do things?, which in this case is to produce a quality product at minimum cost. The cost of operation will depend not only on the cost of the raw material but should include that incidental to the process. The manufacturer does not control the price of fuel but he can to a great extent control the quantity used by the selection of a furnace and fuel adapted to his individual plant conditions. The amount of fuel used will depend on the design of furnace, nature of the operation, and the operation of the furnace. The design of the furnace has its greatest influence on the amount of fuel used in production while the nature of the operation largely influences the amount of fuel used in starting and stand-by operation.

In considering the fuel cost too much emphasis has been laid on the heat value of the fuel, its combustion and the generation of heat, and too little attention has been given to its proper utilization. Many absurd comparisons are made between different fuels, based merely on their heat content, but it should be noted that while a change in the form of energy increases the unit cost of the energy it does not necessarily increase the cost of the ultimate result sought. The ultimate cost is largely influenced by the method of utilizing the energy in its new form.

To reduce labor costs means necessarily increasing the productiveness of the worker. High wages may or may not tend to reduce labor cost; reduction of working hours may or may not reduce labor cost. Labor turnover is influenced largely by the location of the plant.

The use of power is usually considered as an expense. The power required in industrial heating operations is for the most part used in driving the auxiliaries and in handling the work to and from the furnace. Where furnaces are operated with the air for combustion applied by a power-driven unit, the cost of the power is often regarded as an unnecessary expense when compared with stack or natural draft. It will usually be found, however, that the better control of the heating operation both in time and uniform heating conditions, more than justifies the cost of the power used.

This same idea would hold in providing for the generous use of power in the operation of auxiliaries, in the reduction of manual labor and more particularly in handling the quenching medium. In many cases atmospheric cooling of the quenching medium is sufficient to maintain the temperature within the required limits, while in other cases the volume of the output and rate of production requires the installation of a more effective cooling system, which in turn may mean a refrigerating plant. Charging and discharging machines, conveyors and quenching devices represent a justified outlay for power.

Rejected material is not only a direct loss, represented by the raw material, labor, power and fuel costs, but reduces the productive capacity of a plant. Rejected material may be due to defective raw material; sometimes to poor design where the piece is ill-adapted to the treatment proposed, that is while the piece may be treated individually with fair success, by its shape or form it does not lend itself to mass production.

Imperfect heating, due to an overloaded furnace or to improper preliminary or previous treatment, is a common cause for rejected material. The barbarities of the forge shop sometimes render the after treatment distinctively a salvaging operation rather than a normal processing one. Socalled "hospital operations" are costly and the return of salvaged or reprocessed material means only a saving of the cost of the raw material, while all the other items of operating cost are lost and appear twice in the cost of operation. Maintenance charges, apart from a direct item in the cost of operation, should be credited at least as an item of insurance offsetting to a considerable extent the shutdown hazard.

For purposes of distribution, manufacturing costs may be assumed to be made up of material costs, labor costs, and expense, including with expense the item of fixed charges. Material and labor costs may be readily obtained and the nominal cost of operation will be materially affected by the method employed in the distribution of expense. The view is advanced that fixed charges on floor space, equipment and material should be departmentalized and that those items of expense that vary with the output should be segregated and that the cost of the finished product should not be penalized by fixed charges based on the operation of the entire plant.

The foregoing notes outline some of the factors to be considered in the production of a heated product and in essentials may be summarized:

To produce quality product at low cost, it is necessary to select a form of equipment and fuel adapted to the individual plant conditions, which, when properly combined and operated, will produce the results sought.

There are no fixed standards to determine definitely the form of equipment or fuel to use.

Fuel and equipment should be selected for what it can do under specific conditions. The heat unit standard is not a real test of the value of the fuel, nor is the heat balance standard a real test of the value of equipment. Due consideration must be given to the form of fuel and equipment selected for an industrial heating operation and both must be selected with regard to the manufacturing requirements and the plant conditions.

DISCUSSION OF MR. BROWN'S PAPER

MR. LUDWIG: The American Society for Steel Treating as one of the high-class scientific societies in America, I believe, should consider some terms used in heat treatment and furnace constructions more thoroughly than has been done heretofore. I have often heard here in this meeting, and also in technical literature, the terms "reducing" and "oxidizing" atmosphere, or "reducing" and "oxidizing" flame. Now those terms are highly misleading. As some experiments show very clearly there is no such thing as generally reducing or generally oxidizing flame. It is understood that a reducing flame is a flame which has more fuel than necessary for the original amount of air, and oxidizing flame is a flame which has more air than is necessary for the commercial fuel. We call reducing action an action which reduces oxides to metals and consequently we should think that the reducing flame will not reduce the scale on steel. Steel treaters especially use the term "reducing" flame, but what we actually observe is that the socalled reducing flame is actually oxidizing on steel. This observation fully coincides with the chemistry of steel, and the chemistry of oxidation and reduction, so that instead of using terms "oxidizing" and "reducing" flame

would it not be much more scientific, much more to the point, to use the terms "lean" flame and "rich" flame?

CHAIRMAN: Perhaps some of the furnace men can answer this question. I believe that a great deal of our general practice hinges around some of these words that may not be technically correct, but it is up to the furnace men, I would say, to change our understanding if there is to be a change along this line.

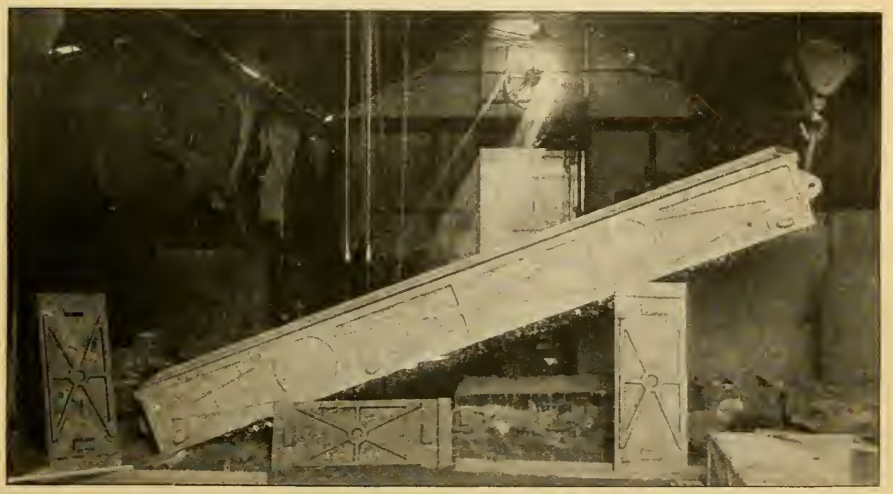
MR. BROWN: Of course the purpose I had in mind was simply to use the terms perhaps in their ordinary sense. That is, the paper, in itself, covered the subject of heating a little more broadly than would be desirable from your particular point of view. For instance, in open-hearth practice there is a definite oxidizing action, and I would rather, of course, hear some other gentlemen give their views as to the proper use of those terms, in other words, not to bring it down to simply a question of terminology but to develop a term or decide what a certain action in handling a furnace does to the metal. That is, do we injure the metal or do we protect the metal? That is really the point desired to impress.

MAKING ALLOY ANNEALING BOXES IN ENGLAND

(Reprinted by permission of The Foundry)

A considerable industry has been built up in Great Britain for the manufacture of chrome-nickel alloy castings. This industry centers in Sheffield, the alloy being chiefly used for the manufacture of annealing boxes, pots, tubes, retorts, etc., used in connection with the heat treatment of high-speed steel. Chrome-nickel alloy castings are being made for these purposes up to 2½ tons in weight. This alloy is said to have special fire resisting and corrosion resisting characteristics.

One of the leading manufacturers of chrome-nickel alloy castings is Kent Smith, Ltd., Sheffield. The accompanying illustration shows an annealing box made of chrome-nickel alloy in the Kent Smith foundry. This box is used for heat treating mill lengths of high speed steel. The



—*Courtesy The Foundry*

CAST CHROME-NICKEL ANNEALING BOX WEIGHING OVER TWO TONS

casting is 16½ feet long and weighs 4750 pounds. The castings are molded in sand in the ordinary way, and the chrome-nickel alloy is melted in furnaces similar in a general way, to those used for nonferrous metals.

HEAT TREATED STEEL CASTINGS OF CHROME-MOLYBDENUM STEEL

Some experiments recently made in the production of chrome-molybdenum alloy steel castings by the Michigan Steel Castings Co., Detroit, afforded interesting results according to *The Iron Age*. The steel was made in electric furnaces and the castings, which were of various sizes, were subjected to a special heat treatment. The composition was approximately:

	Per Cent		Per Cent
Chromium	1.00	Carbon	0.27
Molybdenum	0.50	Manganese	0.94

The heat treatment to which the castings were submitted was as follows: Annealing at 1650 degrees Fahr. and held for 2 hours at 1575 degrees Fahr., then quenching and drawing at the different temperatures shown in the table of results.

The physical tests of the test-pieces taken from the castings after heat treatment were as follows:

Drawn at Degrees Fahr.	Elastic Limit Pounds per square inch	Tensile Strength Pounds per square inch	Elongation Per cent	Reduction of area Per Cent	Elastic Ratio Per cent
1050	132,800	141,520	8.0	30.8	93.4
	141,500	153,900	10.5	28.7	91.9
1150	107,440	124,880	18.0	47.9	86.0
	115,600	131,800	14.0	37.3	87.6
1250	81,520	104,000	20.0	50.3	78.3
	88,900	110,400	20.0	43.0	80.5
1300	75,900	99,400	22.0	52.7	76.4
	76,400	103,000	18.5	52.8	74.1
1350	66,600	100,000	21.0	54.1	66.6
	65,800	98,900	21.0	51.1	66.5

A feature of these results was the high reduction of area combined with unusually high tensile strength. Still more striking was the range of elastic ratio. The best results were those showing the greatest elongation and reduction of area, combined with a high elastic ratio, obtained when the drawing took place at 1250 degrees and 1300 degrees Fahr.

It is stated by the company that a number of the castings of the above composition and heat treatment were in the form of 3-inch diameter shafts while others were cast in blocks, which were used by a large steel company as hammer blocks. Some of those in shaft form were used as axles in which service excellent results have been reported while of the hammer blocks equally satisfactory results were recorded.

THE VALUE OF MOLYBDENUM ALLOY STEELS

By Dr. G. W. Sargent*

(A Paper Presented Before the Detroit Chapter)

Although the author has used the word molybdenum for years, every-time he pronounces it, he thinks of the slang expression "you said a mouthful" and sympathizes with those who utter it for the first time. It is unfortunate that the element does not have a more readily pronounced name. Not so long ago, the writer received from Major D. Bashford, dean of the Metropolitan Museum of Art, New York City, a copy of "Helmet and Body Armor in Modern Warfare" and in looking through it, noticed the following foot note: "As this is written I learn from my friend, Dr. M. Mayajima of Tokyo, this interesting point, which he in turn had from the metallurgist, Dr. D. Kochi of the Faculty of Technology of the Imperial University of Tokyo. It appears that years ago a German steel expert analyzed a part of a sword blade made by the famous Japanese artist, Masamune (1330) and he discovered the rare element molybdenum, doubtless as an impurity, in a certain proportion. This lead the discoverer to determine the local source of Masamune's alloy iron; thereupon he purchased this iron in large lots, much to the surprise of the Japanese who later, when they analyzed captured German cannon decided where a part at least of the molybdenum ore was obtained."

*President, Molybdenum Corp. of America, Pittsburgh.

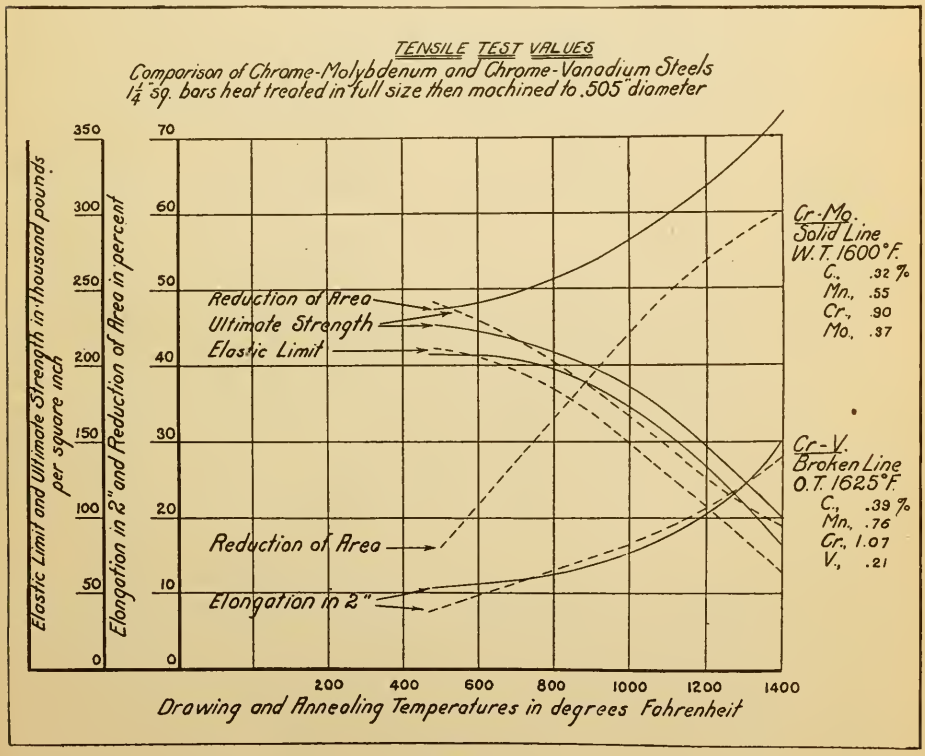


Fig. 1

So it seems that as early as 1330 this element was used in combination with iron.

My own work with molybdenum began in 1890 and in 1894 an article was published on an attempt to produce a theoretically possible molybdenum haloid. In 1899 the first heat of molybdenum steel was made and since then the writer has worked on the various combinations of this element in steels and methods for its estimation.

In 1894 Thomas Blair stated that 1 per cent molybdenum rendered good iron worthless. Dr. Mathews in 1902 contradicted this, but said he found 2.97 to 2.99 per cent molybdenum in steel made it red short. In 1897 Von Lipin states he found 3.72 per cent molybdenum steel hammered better than one containing 3.80 per cent tungsten; furthermore, the former was tougher. Then in 1896 the Creusot works of Schneider et Cie in France set forth that 0.20 to 0.30 per cent molybdenum in 0.20 to 3.00 per cent chromium armor plate steels rendered them less brittle and harder. This was probably the first instance of the use of the chrome-molybdenum combination for the production of tougher steels. Brierly and Ibbotson in 1902 state that experimenters are by no means unanimous with respect to the influence of molybdenum on the mechanical properties of steel, and according to their investigations of the commercial molybdenum alloys available, "it would be surprising if they were." Here then is the explanation of the contrary reports, and with it the author agrees since his own experience with the ferromolybdenum available in the earlier days confirms this.

Between 1902 and 1904, a number of molybdenum steels were made at the Creusot works in France and the *Iron and Steel* magazine for 1904 gives the heating and cooling curves of the following steels as made by E. Saladin, metallurgical engineer of these works:

Carbon per cent	Nickel per cent	Chromium per cent	Molybdenum per cent
0.28	...	...	1.83
0.11	...	1.48	1.66
0.89	...	1.48	1.53
0.21	2.83	0.58	0.80

Most of these molybdenum steels produced at the Creusot works were used by Leon Guillet of the De Dion Bouton Cie for what were the first systematic investigations. The pearlite molybdenum steels show a yield point much higher than ordinary steels, but in spite of this, Guillet says "they have high elongation and good twisting strength, they are not more brittle than carbon steels, but are perceptibly harder." In other words, in 1904 Guillet pointed out that the commercial molybdenum steel which is used for structural purposes should not contain more than 1.0 per cent of molybdenum.

Gustave Gin in "The Electrometallurgy of Rare Metals," American Electrochemical Society, 1907, states that "molybdenum increases largely the ductility and elasticity of hard steels, for 0.25 per cent molybdenum will increase the extension to the point of rupture 40 per cent, and the addition of 1.0 per cent molybdenum to chrome steels of great hardness, permits of their being worked rather easily." He adds that "could ferro molybdenum be obtained at less cost and in greater quantity it is certain the consumption of molybdenum would be very much greater."

Thomas Swinden, in the *Journal of the Iron and Steel Institute,* 1911,

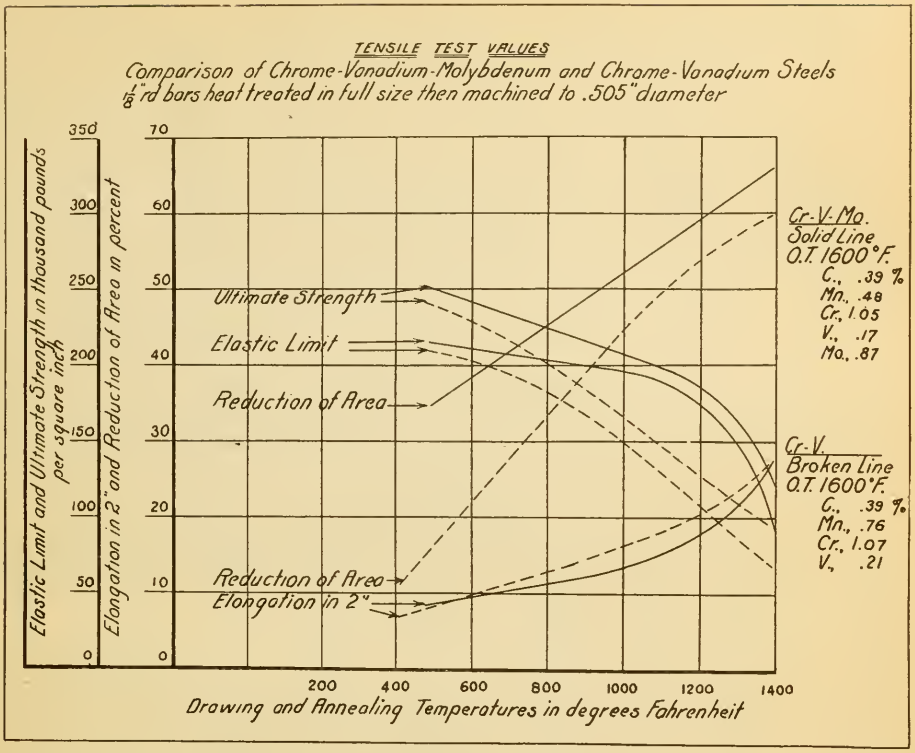


Fig. 2

Carnegie Scholarship Memoirs, Vol. III, investigated four series of molybdenum steels up to 8 per cent content and concludes that the 1 to 2 per cent molybdenum steels show the most interesting physical properties and 1.0 per cent molybdenum gave a most excellent case hardening steel. In making his steels, he recovered 90 per cent of the molybdenum added to the crucible charge and 90 per cent of his ingot weight in finished sound bars. His further study of some molybdenum in alloy steels made in 1913, and published in the *Journal of the Iron and Steel Institute, Carnegie Scholarship Memoirs*, Vol. V. included steels of the following analysis:

No.	Carbon Per cent	Manganese per cent	Silicon per cent	Sulphur per cent	Phosphorus per cent	Molybdenum per cent	Nickel per cent	Chromium per cent	Vanadium per cent
19.....	.15	.22	.058	.020	.019	.53	.098	...	...
20.....	.19	.23	.056	.023	.020	.53	...	.95	...
21.....	.30	.33	.067	.022	.017	.52	...	...	.21
22.....	.33	.28	.075	.023	.021	.96	...	...	...
23.....	.30	.24	.075	.021	.018	.45	.99	...	...
24.....	.32	.28	.082	.021	.019	.46	...	.91	...

Swinden stated: "In the author's previous report several interesting results in mechanical tests were obtained, which gave promise of value as medium tensile steels with good ductility, and a series of mild steels containing molybdenum and other alloys have been prepared and tested." Referring to the tensile test values obtained from these steels after heat treating them, he said: "Steel No. 24 gives promise of being a useful steel of cheaper quality than the high tonnage nickel-chrome steels now on the market which give 110 to 120 tons tensile strength with 10 to 12 per cent elongation. All the steels have notably high reduction of area figures and

in this way resemble nickel and chromium-nickel steels." Under the heading "manufacture," he writes "The experimental ingots have been made by the crucible process, but it is assured that in making any of the steels commercially, the acid open-hearth process would be used." That molybdenum, when alloyed with straight carbon steels, chromium, nickel, nickel-chromium and other alloy steels, imparted to them a further increase of strength and toughness, making of them very desirable commercial steels, has been recognized for years past, but their adoption has been held back on account of the relatively high cost of molybdenum alloys and the uncertainty of the supply, together with the quality of the former. These latter features have now been eliminated, and these molybdenum steels should be even more generally used than nickel or the low grade nickel-chromium steels.

A few words as to the manufacture of these molybdenum steels, then we will pass on to their physical properties. The manufacture of the alloy steels containing molybdenum is no more difficult than the same without molybdenum; in fact, general experience indicates that the molybdenum increases the yield from ingots to shipped bars with less losses due

Table I
Analysis of Molybdenum Steel Ingot Drillings

Number specimen	Carbon per cent	Manganese per cent	Phosphorus per cent	Sulphur per cent	Silicon per cent	Nickel per cent	Chromium per cent	Molybdenum per cent
Ingot No. 192724 Bl								
Heat	.390	.53	.031	.026	.218	.18	1.02	.35
M1	.380	.51	.031	.023	.235	...	1.00	.37
M2	.398	.48	.031	.026	.210	...	1.04	.34
M3	.426	.47	.035	.028	.204	...	1.06	.38
M4	.420	.53	.032	.027	.215	...	1.05	.37
B1	.368	.50	.030	.021	.206	...	1.02	.39
B2	.390	.43	.031	.020	.240	...	1.04	.34
B3	.380	.51	.030	.023	.240	...	1.02	.37
B4	.350	.47	.026	.023	.235	...	1.00	.34
Ingot No. 192734 Bl								
Heat	.400	.45	.044	.033	.204	1.61	.08	.43
M1	.398	.46	.035	.032	.195	1.68	...	.44
M2	.394	.46	.035	.037	.197	1.70	...	.47
M3	.402	.46	.038	.042	.198	1.70	...	.48
M4	.442	.47	.042	.046	.184	1.70	...	.48
B1	.374	.46	.033	.023	.179	1.68	...	.45
B2	.364	.46	.033	.031	.190	1.64	...	.44
B3	.312	.44	.031	.029	.174	1.68	...	.40
B4	.308	.43	.026	.025	.174	1.65	...	.40

* Data obtained through courtesy of R. M.Bird.metallurgist Bethlehem Steel Co. Specimens taken across top and bottom cuts of two 40-inch corrugated ingots.

to seams, pipeage, and discards. These steels may be melted in the crucible, basic or acid open-hearth, and the author believes should it be desirable, in the bessemer converter.

If the crucible process is employed, the ferromolybdenum is placed in the crucible with the last two-thirds of the charge, after the practice of making tungsten steels. Molybdenum powder, similar to tungsten powder, may be used, but on account of its high melting point and the impurities usually present, the recovery of molybdenum in the finished steel is less than is the case when ferro with its melting point around 1550 degrees Cent. for 50 to 60 per cent molybdenum. Molybdenum powder, amorphous metal, melts between 2500 and 2550 degrees Cent. and its uniform diffusion throughout the melt does not always take place. The advisability of using ferro is apparent, and calcium molybdate should never be used in the crucible process. In using the ferro, practically all the molybdenum added to the melt will be recovered in the ingot metal and this is also true of the basic or acid open-hearth practice.

In following the open-hearth practice, the ferromolybdenum is added before the ferrochrome and after the slag has been cleared up, that is to say,

generally freed from oxides by the usual methods. Molybdenum steel scrap may be remelted without loss, or very little at most of the molybdenum. In this respect it behaves like nickel. Some of the types of these molybdenum steels are: Chrome-vanadium-molybdenum; chrome-molybdenum; nickel-molybdenum; nickel-chrome-molybdenum; manganese-molybdenum; silicon-molybdenum; and silico-manganese-molybdenum.

The physical characteristics of some of these steels are shown by the following charts, Figs. 1 to 5 inclusive, a study of which shows their merits. The uniformity of these molybdenum steels is shown by Table I of analyses of four sets of drillings taken across top and bottom cuts of two 40-inch corrugated ingots. These drillings were numbered from the outside towards the center. From this table it is evident that molybdenum does not segregate or cause segregation.

In the comparison charts, it will be observed in the case of the molybdenum steels, that as the drawing temperatures are raised up to 1000 to 1200 degrees Fahr. to further increase the toughness, the decrease in ultimate strength and elastic limit values is less than is the case with the other steel compared. Furthermore, reductions of area which is the best measure of the toughness of the alloy steels is generally greater.

The molybdenum steels as a whole in the rolled or forged condition, show uniformly higher ultimate strength and elastic limits with greater elongation and reduction of area. Data for this is shown as follows:

	Ultimate strength, Lbs. Sq. In.	Elastic limit, Lbs. Sq. In.	Elongation in 2 inches per cent	Reduction of area per cent
No. 1 chromium molybdenum as rolled 1-inch round....	140,000	105,000	15.0	32.0
No. 2 nickel molybdenum as rolled 1 inch round	120,000	93,000	18.0	39.05

Analysis of Specimens

	Carbon per cent	Chromium per cent	Nickel per cent	Molybdenum per cent
No. 1	0.40	1.00	...	.35
No. 2	0.40	...	1.50	.40

The elastic limit of No. 1 as rolled together with its easy machining qualities, for it machines as readily as the 70,000 pound per square inch elastic limit manganese steel used for gun barrels, recommends it for the purpose.

The effect of various quenching temperatures on the tensile test values of the chrome molybdenum steels is shown by the following table and chart:

Quenching temperatures degrees Fahr.	Ultimate strength, pounds per square inch	Elastic limit, pounds per square inch	Elongation per cent in 2 inches	Reduction of area, per cent
1550	160,925	156,625	18.0	62.2
1600	155,850	149,925	17.5	60.2
1650	156,375	145,775	17.0	60.2
1700	153,450	141,570	17.0	60.1
1750	154,350	142,500	18.0	60.0
1800	154,900	144,000	17.5	59.0

Drawing temperature 1000 degrees Fahr. Quenching medium water. ¾-inch round bar used in tests. Analysis: 0.30 per cent carbon; 0.70 per cent chromium; 0.35 per cent molybdenum.

A microscopic study of the structure of most all these steels shows great similarity in that when quenched and drawn from 350 to 1100 degrees Fahr. they reveal a fine uniform distribution of the constituents, so much so, that the structure of the specimen drawn at 1100 degrees Fahr. which presumably contains ferrite and pearlite, but possess a pseudo-martensitic

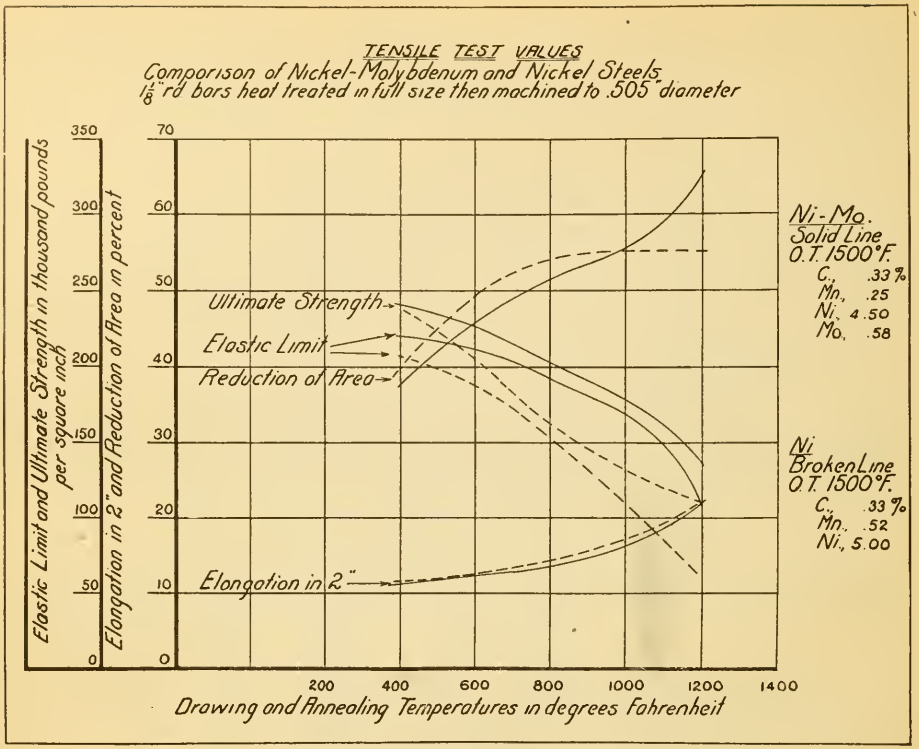


Fig. 3

structure, cannot be readily distinguished from that drawn at 350 degrees Fahr.

Except in the case of lower molybdenum content steels, which show when drawn as high as 700 degrees Fahr. a martensitic, or pseudo-martensitic structure; otherwise even these are alike as the following studies show. When heated after quenching to 1400 degrees Fahr. the ferrite separates out distinctly from the pearlite, which latter takes a more true pearlitic structure. In other words, the steel becomes annealed.

Molybdenum steels are economical not only in their first cost but also to handle through the manufacturing stages. They will save money in machining and they will save money in heat treating, and they forge as readily as carbon steels.

Now, as to the available supply of molybdenum, it is chiefly obtained from the ores molybdenite and wulfenite, MoS_2 and $PbMoO_4$. The former is the most important and most widely distributed. It is stated that Queensland and New South Wales Australia were for many years the largest producers; in 1906 100 tons of MoS_2 were produced. Norway is said to have produced in 1915 87 tons of MoS_2. Canada produced 135 tons of MoS_2. Although the author has no reliable statistics of the production in the United States, he is of the opinion that the year 1918 saw 250 to 300 tons of MoS_2 produced. Of this nearly 200 tons were manufactured into ferromolybdenum by the Electric Reduction Co., Washington, Pa. now the Molybdenum Corp. of America. This molybdenum found its way into light armor plate for tanks, etc. and into Liberty motors.

The recent discovery of large rich deposit of MoS_2 in northern New Mexico and the development of the Colorado mines assure a supply of ore sufficient to meet any demand that may come through the extensive use of the molybdenum alloy steels.

The deposit has been developed during the past year and it is conservatively estimated to contain 60,000,000 pounds of MoS_2 in the group of veins now being worked. This group is located at the southern end of the property. Other and larger groups exist just north and parallel to these. The ore is high grade, easily mined and concentrated, since it is massive and not diffused through the rock as is the case in the Colorado deposits. The ore varies from 1.5 to 29 per cent MoS_2 and the veins vary from a few inches to 30 feet in width. The development in the present working warrants stopping the work for a width of 9 to 30 feet and a height of 600 feet.

Plans for the erection of a power plant on the Rio Grande and a mill capable of producing a million pounds of molybdenum annually have been prepared and work is expected to be started on the ground this spring. The corporation plant at Washington, Pa. is now capable of reducing this quantity of molybdenum to ferromolybdenum sufficient for the manufacture of 125,000 tons of 0.4 per cent molybdenum steel. The design of the mill is such that it can readily be added to and the capacity doubled. The present mill has a capacity of about a ton per day of MoS_2 concentrates.

From the foregoing it will be appreciated readily that there is plenty

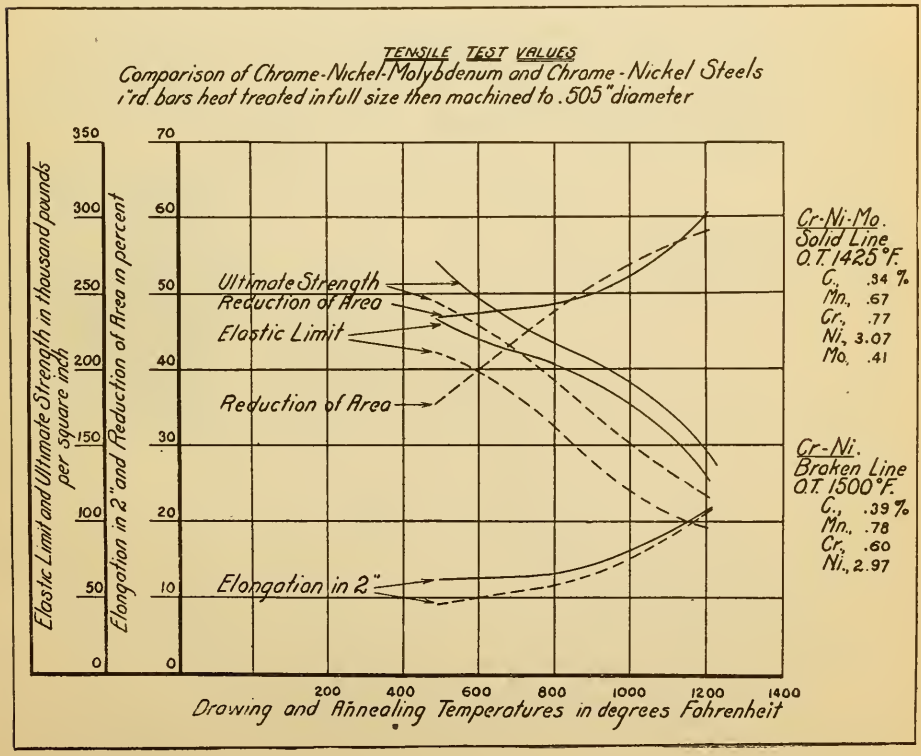


Fig. 4

of molybdenum available to meet the demand as it comes through the greater appreciation of the value of molybdenum alloy steels.

DISCUSSION OF DR. SARGENT'S PAPER

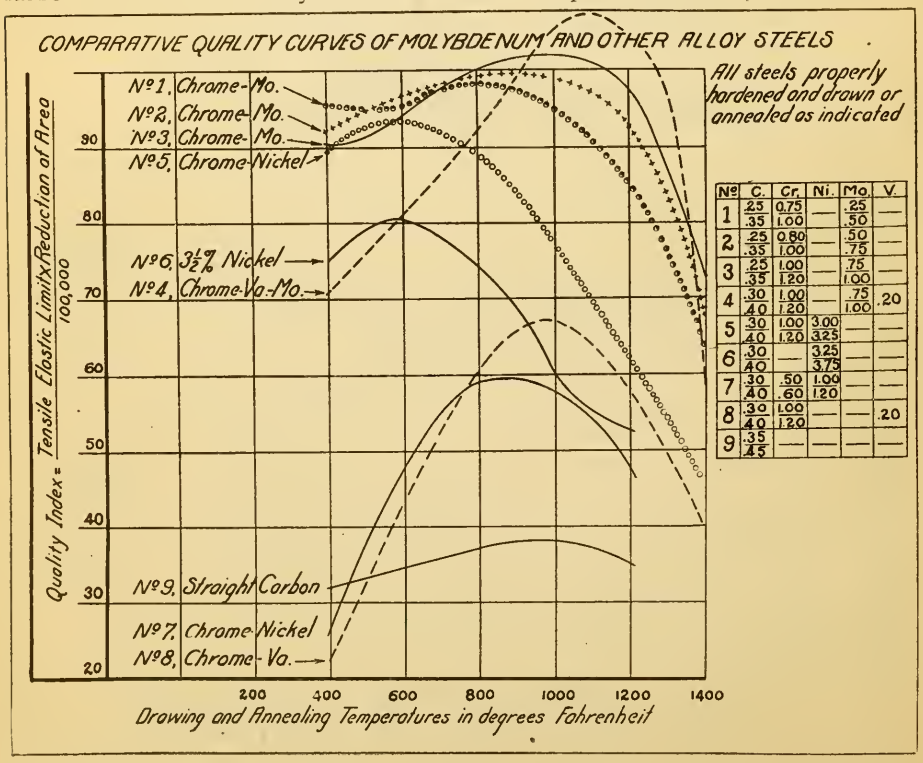
MR. DANSE: Dr. Sargent has stated that this steel is easily machined. I would like to ask that he give us the comparative machinability of chrome-nickel and chrome-vanadium steels.

DR. SARGENT: I cannot give you a comparison in figures, or say that you can turn out so many hundred gears in a certain length of time, but I think there are gentlemen here who can, perhaps. In turning up test pieces, I have noted personally the easy machining of the chrome-molybdenum steel. I have received reports from various factories and from the testing departments that the chrome-molybdenum steel machines as readily as straight carbon steel, and this comes from those who have handled many tons of the steel.

MR. DANSE: The straight carbon steels have a manganese and carbon content specified. Is there a manganese and carbon content specified in the molybdenum steels as in the straight carbon steels?

DR. SARGENT: Yes, as in the other alloy steels.

MR. DANSE: The Ford Motor Co. has done more work with these molybdenum steels than any others that I know of. They take straight carbon in which the molybdenum will be 1.05 per cent, straight nickel with



Nº	C.	Cr.	Ni.	Mo.	V.
1	.25 .35	0.75 1.00	—	.25 .50	—
2	.25 .35	0.80 1.00	—	.50 .75	—
3	.25 .35	1.00 1.20	—	.75 1.00	—
4	.30 .40	1.00 1.20	—	.75 1.00	.20
5	.30 .40	1.00 1.20	3.00 3.25	—	—
6	.30 .40	—	3.25 3.75	—	—
7	.30 .40	.50 .60	1.00 1.20	—	—
8	.30 .40	1.00 1.20	—	—	.20
9	.35 .45	—	—	—	—

Fig. 5

1.35 per cent molybdenum. I was wondering if you used chrome-molybdenum or straight molybdenum in your machining tests.

DR. SARGENT: It seems that small amounts of molybdenum improve the machining qualities of the alloy steels to which it is added. I think you will find the molybdenum steels somewhat easier to machine.

MR. MADRE: I would like to mention a few troubles we experienced when we started to use molybdenum about three years ago. The first thing was hard forged dies, the analysis of which was: Carbon 0.60; chromium 3.60; vanadium 0.50; and molybdenum 0.35 per cent. We noticed that most of the dies cracked when we put them in oil and left them during hardening. We were inclined to believe that the trouble was due to the molybdenum and consequently the use of molybdenum was stopped. I do not know exactly whether our analyses were off or not. Secondly, we started to use molybdenum in crankshaft steel: Carbon 0.28 to 0.32; chromium 0.90 to 1.10; manganese 0.60 to 0.80; and molybdenum 0.30 to 0.40 per cent. In this analysis, we replaced molybdenum with 0.18 per cent vanadium, and the first thing we found was that the machinability was far less as compared to vanadium steel, and especially that the drilling on some of our bars was hard as compared to vanadium steel. Also, we noted the fact that some of the crankshafts when they were put in the condition of 50 to 60 Shore hardness cracked. Therefore, we gave up the use of molybdenum. I do not know exactly whether it was the use of molybdenum or something else. In the foregoing, manganese was never above 0.50 per cent while in the crankshaft manganese was between 0.60 and 0.80 per cent. From the charts I have noticed that in all these your manganese does not run above 0.50 per cent.

DR. SARGENT: I could not give you a correct answer as to the cause of all your troubles, perhaps, but I would say at once that with 3.5 per cent of chromium in die block steel, you were very very high, obtaining a hard alloy steel. That much chromium is away beyond the commercial range of any chrome steels for this purpose, even in projectile steels. I remember well that we never made a successful projectile in the olden times with more than 3 per cent chromium. We tried to keep it down to 2.75 per cent as a maximum. If we went higher and the shells were in the neighborhood of 0.65 to 0.75 per cent carbon, we had bad losses in their heat treatment. It would be a rather ticklish steel to handle with all the hardening elements you mention as being present in your die block steel.

Now as to the crankshafts breaking, it may be that you had too much carbon with too much manganese for a water hardening steel. The steel for crankshafts does not need to be so high; in fact, I recommend strongly that you keep under 0.30 per cent carbon. You can go to 0.32 or 0.33 per cent carbon, but it is best to keep the carbon down and the manganese within the usual limits, and you can water hardening without any trouble. I think that is probably one answer to your troubles. Your steel might also be segregated due to the methods employed in its manufacture. If we had some of the steel available, we could dig into it and could probably find out more definitely the cause of your troubles and a way to eliminate them.

MR. MADRE: Do you think that 0.32 per cent carbon with 0.45 per cent molybdenum is too strong a combination?

DR. SARGENT: No. With 0.32 per cent carbon and 0.40 per cent molybdenum and 0.70 to 0.80 per cent and sometimes even as high as 1 per cent chromium, you will have no trouble with your crankshafts, provided, of course, that your heat treating and forging practices are not abnormal.

HIGH TEMPERATURE RESISTING ALLOYS FOR CARBONIZING

By A. Bensel*

(A Paper Presented by Title at Philadelphia Convention)

Carbonizing, as will be dealt with in this article, is the process of heating a low carbon steel in intimate contact with carbonaceous material at a temperature just above the upper critical point of the steel for such a period of time as is necessary to produce a carbon penetration of the required depth. It is not necessary to elaborate on this process from a technical standpoint as steel treaters are so well versed on the subject.

Since the object of this article is to set forth the desirability of good heat resisting containers, mention should be made of the standard methods of case hardening which employ these containers. The methods in question are:

1. Pack Carbonizing
2. Liquid Bath Carbonizing
3. Gas Carbonizing

The first method consists in packing the low carbon steel parts to be treated with solid carbonaceous compound in a suitable container and in heating to a temperature just above the upper critical point of the steel for the length of time necessary to obtain the depth of carbon penetration required. This method is used mostly for the larger sized pieces where a large area of surface must be carbonized. The shape of the containers will vary according to the shape of the pieces to be treated, being either rectangular, circular, or circular with a chimney in the center.

Liquid bath carbonizing consists in keeping a fused liquid bath in some suitable container at a temperature above the upper critical range of the steel and then dipping the pieces to be treated into this bath for a short period of time, usually 10 to 12 minutes. This method is used mostly for small pieces and where a very thin case is all that is required. The pieces are placed in some type of dipping basket and in this manner kept under the surface of the bath during the time interval required. A sodium cyanide-sodium chloride mixture is the most widely used material for this liquid bath method.

Gas carbonizing consists in utilizing a gas to furnish the carbon to the steel to be treated on the theory that it is the gas developed by the dissociation by heat of the solid carbonaceous material used in pack hardening that is the active agent. In this method the gas is used directly on the steel without having it formed by dissociation. The equipment for this method usually is a horizontal retort rotating in a combustion chamber fitted with a suitable burner equipment for securing the proper temperature, which as in the previous methods, must be above the upper critical point of the steel pieces. The pieces are put into one end of the retort and are discharged at the opposite end, after the proper time interval. Gas is forced into the retort and as the temperature is correct for carbonizing, the steel absorbs carbon readily.

All three of these methods have their advantageous use dependent upon the work to be done. It is of special importance that a suitable container be selected in each of the three methods. This container must be capable of confining all of the gases, carbonaceous material and liquid to produce uniformly good results, and this capability must not be affected by the temperature to which the container is subjected. The ob-

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ject of this article is to deal especially with the carbonizing containers capable of withstanding high temperature and oxidation for long periods.

It is a well known fact that cast iron and steel carbonizing containers are badly distorted in a relatively short time with the result that it is impossible to load a furnace evenly with these boxes of unequal dimentions. Therefore, we have by the use of high temperature resisting alloy containers the very important advantage of greater furnace capacity resulting in increased production. An important consideration is that of scaling for the clinging scale is an insulator, making the heat penetration poor. When the scale drops off and the walls are consequently thinner, the heat penetration is thereby affected and the work in process either receives too much or too little heat, depending on whether a new or an old container is used.

The containers should be of material not easily carbonized so that the efficiency of the carbonaceous material is not lowered by part of it being utilized to carbonize the container, thus leaving the contents undertreated. They must not be brittle for in service these containers receive rough usage while hot, and brittle containers would crack or break up under the severe treatment. They should be capable of being machined as machining operations are often necessary in order to get a tight fitting cover. They should be made of material which has a high tensile strength and which will retain much of that strength at the usual operating temperatures. The service of these containers should be such that the proportion of service to price makes their cost per hour reasonable.

Until recently all these containers were cast of either iron or steel. They were deficient in practically every one of the requirements above mentioned, especially the one least thought of, namely that of cost price per hour of service rendered. It was evident to every one interested in the process of carbonizing that some alloy would be necessary to meet the requirements; not an alloy steel because it scaled badly, warped and only increased the cost, but a really high grade heat resisting alloy. It has been said that "No one metal is a cure-all", but it would seem that an alloy which would cast successfully, was not so hard that it could not easily be machined, had a high tensile strength which it retained at high temperatures, was not brittle, and above all resisted successfully high temperatures neither scaling nor warping, surely, such an alloy would have cured all the ills that at least carbonizing containers were heir to.

In developing an alloy of this kind it was obvious that to resist high temperatures successfully it would necessarily have to possess a high melting point. Certainly then it would have to be alloyed of metals having high melting points. It was necessary also that these metals alloy themselves homogeneously so that there would be no segregations and the castings would be uniform throughout.

From metallurgical experiences it was evident that whatever this alloy might be, it must necessarily contain chromium in rather large quantities because this element is necessary to prevent scaling at high temperature. This was clearly proved in the work done in developing a suitable metallic electrical resistor. Many alloys could be made that had the proper electrical resistance but in this case, as in the case of carbonizing containers, heat resistance also entered into the problem. For a period of about 14 years no alloy without chromium in large proportion has been found that will resist destructive scaling at temperatures of 1600 to 2000 degrees Fahr.

The alloy then to be successful must contain chromium, but what else? It is well known that nickel and iron alloy perfectly with chromium. We have evidence of this in the homogeneous nickel-chromium steels and also in the nickel-chromium alloys which are used for electrical resistance purposes.

From all past metallurgical experiences, it is safe to say that until some new metal of high melting point is discovered to replace chromium in heat resisting alloys, nickel-chromium alloys will excel for carbonizing containers.

To obtain in regular production the excellent characteristics of this alloy its making must be carefully regulated. The electric arc furnace is best adopted to its melting and the company with which the author is connected has two such furnaces and of 2-ton capacity. Not only is the melting done under the most approved metallurgical conditions, but the molding operations must embody care and attention and methods peculiarly requisite to a metal of large shrinkage and relatively high freezing temperature. The following technical data on the alloy may be of interest. Analysis:

Nickel, 60.0 per cent.
Chromium, 12.0 per cent.
Iron, 26.0 per cent.
Carbon, silicon, manganese, etc., 2.0 per cent.

Melting point, 2660 degrees Fahr.
Safe working temperature, 2000 degrees Fahr.
Specific gravity, 8.15.
Weight per cubic inch, 0.29 pounds.
Specific heat, 0.111 at 100 degrees Cent.
Brinell hardness number, 179.
Sclerescope hardness, 27 to 30.
Coefficient of linear expansion over temperature range from 0 to 100 degrees Cent., 0.0000121.

Thermal conductivity is 0.0341 calories per centimeter per second or a ratio of 1 to 4.88 with soft iron. Expressed in percentage, 20.5 per cent. of the thermal conductivity of soft iron. Tests were made on a 1-inch diameter specimen.

Tensile tests at 70 degrees Fahr.
Elastic limit, 40,000 pounds per square inch.
Ultimate tensile strength, 54,000 pounds per square inch.
Per cent. elongation, 1.00 per cent.
Per cent. reduction of area, 2.50 per cent.

Tensile tests at 1500 degrees Fahr.
Elastic limit, 20,100 pounds per square inch.
Ultimate tensile strength, 24,500 pounds per square inch.
Per cent. elongation, 4.00 per cent.
Per cent. reduction of area, 4.30 per cent.

From a mechanical standpoint it is evident that nickel-chrome steel is good material for castings that must withstand high temperatures as its tensile strength at carbonizing temperatures is so much superior to ferrous materials. This property is directly applicable to carbonizing containers because the wall thickness can be made very light and yet have the required strength, thus increasing heat penetration, reducing length of heat, and thereby effecting proportionate savings of fuel. When cast it will bend at either red or white-heat. It does not become easily fatigued.

This fact can be demonstrated by supporting a plate of used cast metal at the four corners and striking the unsupported center with a sledge, thereby bending it.

Attention should be directed to an unique design of carbonizing container which was made possible by the desirable properties of the alloy which allow it to serve for thousands of hours at 1800 degrees Fahr. without cracking or scaling. This design is a round container with a machined taper-fit cover, which fits tightly into the container and effectively closes it as a ground glass stoppered bottle. The machined cover fits the taper of the container as well after several thousand furnace hours as when it was first used and this result in itself shows the absence of warping and scaling.

It should be the consideration of every engineer or metallurgist that his container cost per heat hour be a known fact. This enters directly into production costs and his expense of heat treating manufactured parts cannot be analyzed accurately otherwise. The first cost spread over the active life of the container is the item of interest in the expense of the heat treating department. Protective service guarantees are therefore desirable.

CARBORUNDUM REFRACTORIES IN HEAT TREATING FURNACES

By M. L. Hartman*

(A Paper Presented by Title at Philadelphia Convention)

The use of carborundum refractories in certain parts of heat treating furnaces has given such satisfactory service in cases in which they have been tried, that it seems worth while to discuss briefly the refractory requirements for these furnaces, and to point out the particular value of carborundum refractories in them.

In general, nearly all furnaces for heat treating are so constructed that heat must be conducted through a refractory material from the combustion chamber to the pieces being treated. In order to increase production and also because of the nature of the fuels used, the temperatures reached in the combustion chambers are much higher than those in the treating compartment. In other words, it is decidedly advantageous to have a refractory material of high thermal conductivity separating these two compartments so that heat will be transferred rapidly and economically and the temperatures will be uniform throughout.

On account of the difference in temperature on the two sides of the refractory, resistance to spalling is a property greatly desired. Low coefficient of expansion is also preferred, because the tendency to crack is decreased. Cracks may cause hot spots on the treated pieces, and consequent irregularity of product.

In some cases the refractory pieces are required to carry heavy loads at the high temperature, thus it is quite important that they have great mechanical strength. The plates or tiles also must be supported on piers or checker work which remains rigidly in place, with no softening, slagging or cracking.

Another requirement for the refractory used in the treating floor is that is must resist the action of the scale which comes from the steel under treatment or in some cases from the containers. This especially is

*Director research laboratory, the Carborundum Co., Niagara Falls, N. Y.

important in some classes of work where much scale and high temperatures are encountered.

As stated above the combustion chamber itself is subjected to high temperatures, and in order that the heat be generated regularly and evenly, the firebox linings must not become distorted by cracking or softening of refractories. In oil and gas-fired furnaces the refractories and baffles, which are subjected to the impinging flame, must be of the highest grade material. They must withstand sudden changes of temperature without cracking or spalling and must not become distorted by softening under the high local temperature.

In order to have clearly in mind the distinguishing properties of carborundum refractories, it may be well to state briefly the physical and chemical characteristics of silicon carbide—the primary material in all of them.

Carborundum is a product of the electric furnace and is produced by the chemical reaction between coke and silica sand. This crystalline product, carborundum, or silicon carbide, is not melted at any temperature up to the decomposition point, which is about 4064 degrees Fahr. (2240 degrees Cent.) It conducts heat about seven times as rapidly as fireclay, and better than any other refractory material. The change in volume with change in temperature is almost negligible, and there are no physical transformations at any temperatures below decomposition. Carborundum is quite resistant to chemical action, being inert to nearly all reagents except basic substances at high temperature.

Carborundum refractories, being composed principally of silicon carbides, inherit these desirable properties, and the variation in the properties of the different carborundum products is produced almost entirely by change in the bonding material used. For example, the most refractory of all the carborundum products is the variety which is made entirely of silicon carbides, without any bonding material. This is manufactured by a special process in which the silicon carbide crystals intermesh and interlock to form a rigid body.

This recrystallized material is difficult to produce in any but the most simple shapes, since for many furnaces, such extreme refractibility is not necessary, other carborundum refractories have been developed using the smallest possible amount of bonding material to hold together the silicon carbide particles. Variations in the nature of this bonding material have made possible the production of several kinds of bonded refractories each having the required properties for its particular uses. More or less intricate shapes of these materials may be moulded and kiln fired and the finished products have the refractory properties of carborundum slightly modified by the nature of the bonding agent.

While carborundum shaped refractories were being developed, it became evident that for laying up or patching these high grade bricks and shapes, it was necessary to use raw refractory mixtures of similar composition in order to avoid the fusion, cracking and general undesirability of the common mortars and cements. A complete line of carborundum cements therefore was developed, having variation in properties of bonding material to fit every requirement for laying up new work, patching old installations or moulding up special shapes in place. To illustrate how well these materials have served in heat treating furnaces, a few service reports from our records may be of interest.

A number of heat treating furnaces in a large plant in Rhode Island have been provided with carborundum hearth tiles. These have lasted 28 to 30 weeks of continuous use, whereas clay tiles were replaced every two weeks. These furnaces are used for hardening speed steel cutters, and the operating temperature is around 2300 degrees Fahr. (1260 degrees Cent.)

At a machinery manufacturing plant in New Hampshire, carborundum floor tile, supports and linings have been installed in two large carbonizing furnaces. One of these is fired with hard coal and the other by means of oil and both are operated from 50 to 150 hours per week. Both furnaces have been in operation for condition as when installed. The previous fireclay linings lasted only from four to six weeks. A notable economy in fuel consumption is also apparent. This is estimated by the operation at about 25 per cent saving.

Carborundum floor tile have been adopted for all high speed tool steel hardening furnaces in one of the largest motor car plants in Detroit. This company reported that carborundum was the most satisfactory material it had tried, because it was not affected by changing temperatures, and did not soften and distort under heavy load as did fireclay tiles.

At the two other motor companies in Detroit, carborundum floor tile have been giving long service, and after nine or ten months are still in use. Another Detroit manufacturer of tools has been using carborundum hearth plates at 2450 degrees Fahr. (1340 degrees Cent.) for six to eight months. More uniform heating results from their use. In the same furnaces fireclay hearths failed by cracking and slagging and were replaced every four and five weeks.

Near Chicago, a carborundum slab in an underfired gas furnace for high speed steel lasted from February to November, in the same furnace in which fireclay hearths were replaced every week end. Another operator in this district reported that by sprinkling carborundum grain or dry carborundum cement over his floor slabs each morning he prolonged the life of the refractory plate and kept a smooth clean working surface in his furnace.

Enough has been given in these service records to indicate the particular success which has resulted in the adoption of carborundum refractories in the various heat treating furnaces. While one of the chief objections to the use of carborundum refractories has been its high first cost, it must be pointed out that installation and shut down expenses in many cases greatly exceed the amount paid for the refractory parts. The elimination of extensive repairs more than compensates for the increased first cost. The loss of charges in the furnaces at the time of failure is an important item of expense which is nearly eliminated by the use of refractories which serve so long.

News of the Chapters

NEW HAVEN CHAPTER

At a very interesting dinner meeting of the New Haven section held in the Cafe Mellone on May 28, the following officers were elected for the ensuing year: Chairman, Harry V. Goodwill, superintendent of dies,

IRVING H. COWDREY
Elected Chairman of Boston Chapter

CHARLES M. JOHNSON
Elected Chairman of Pittsburgh Chapter

R. Wallace & Sons Mfg. Co., Wallingford; vice chairman, Major Rupert L. Penny, engineer, 54 West Rock Ave.; secretary-treasurer, Walter G. Aurand, chief chemist, R. Wallace & Sons Mfg. Co., Wallingford; members of executive committee, Clayton L. Phillips, Sargent & Co.; Alvin L. Davis, Scovill Mfg. Co., Waterbury; and Rolland G. Hall, R. Wallace & Sons Mfg. Co., Wallingford, Major A. E. Bellis, Bellis Heat Treating Co., William B. Runk, Robert N. Bassett Co., Shelton, Conn. Chairman Entertainment Committee, William B. Runk; chairman Program Committee, J. W. Black, Geometric Tool Co.; chairman Membership Committee, Walter G. Aurand, R. Wallace Sons Mfg. Co.

An organization meeting of the elected officers and committees was held in the Union League Club, New Haven, June 2, where an informal dinner was enjoyed. After dinner plans were perfected for a membership campaign and it was also decided to hold a shore dinner at Savin Rock on June 24. As this will be the final meeting of the year, the Entertainment and Program Committees are endeavoring to make the meeting a banner one as regards speakers and entertainment.

PHILADELPHIA CHAPTER

About 100 members of the Philadelphia chapter attended the May 27 meeting at the Engineers Club. H. S. Rawdon, physicist of the Bureau of Standards spoke on "Structure and Related Properties of Metals". Mr. Rawdon presented his subject in an interesting and intelligent manner, and the discussion following was very good.

The following officers were elected for the coming year: Chairman,

A. W. F. Green, metallurgist, John Illingworth Steel Co.; vice chairman, H. C. Knerr, metallurgist, Naval Aircraft Factory; secretary-treasurer, A. L. Collins, metallurgist, Ace Motor Corp.; members of executive committee, J. J. Crowe, metallurgist, Philadelphia Navy Yard; D. K. Bullens, Bullens Heat Treating Co.; H. M. Brayton, Frankford Arsenal; Prof. H. Reese, instructor in chemistry, Temple University; J. C. Clark, vice president, E. J. Griffiths Co.

HARTFORD CHAPTER

The annual meeting of the Hartford chapter was held in Jewell Hall of the Y. M. C. A. on June 16. Over 100 were present. The principal speaker of the evening was F. P. Gilligan, secretary-treasurer of the Henry Souther Engineering Co., and nominee for National President of the Society. Mr. Gilligan spoke on the subject of "Steel Research, Its Past and Present". R. K. Newman, secretary of the Frasse Steel Works, also presented a very interesting illustrated paper on the "Fabrication of Steel". The open discussion following the presentation of these papers was very interesting and covered the points brought out by the papers. Consideration was given to the program during the coming year, and discussion was also held with reference to the program for the past year. The new officers for the Hartford chapter are as follows: Chairman, Marcus E. Gere, metallurgist of the New Departure Mfg. Co.; vice chairman, A. H. d'Arcambal, metallurgist of the Pratt & Whitney Co.; secretary-treasurer, James J. Curran, metallurgist of the Henry Souther Engineering Co.; members of the executive committee, D. H. Stacks, C. T. Hewitt, M. E. Blakeslee, L. A. Lanning, C. T. Hathaway, J. J. McIntye.

WASHINGTON CHAPTER

The Washington section of the Society held its June meeting on June 17, in the auditorium of the New Interior Department building, when Enrique Touceda, consulting engineer of the American Malleable Castings Association, gave a talk on the "Manufacture of Malleable Iron Castings". Mr. Touceda covered the complete details of the manufacture of malleable castings and a comparison of their physical properties with that of other ferrous products. Many members of other engineering and technical societies were in attendance, and the meeting was thoroughly enjoyed.

CHICAGO CHAPTER

The June meeting of the Chicago chapter was held on the 16th in the Stevens Building, at 6:30 p. m. There was no principal speaker of the evening, but the meeting was known as "Query Night". The announcement sent out was a form on which the members were requested to write any question or problem pertaining to heat treating which they wished to have answered. They were requested not to sign their names, but to bring the questions and drop them in a box as they entered. A committee of experts, all practical men, was present to discuss thoroughly the questions and problems. This meeting helped to clear up any doubts the members may have had on any phase of the game. The meeting was well attended and proved both profitable and interesting:

SCHENECTADY CHAPTER

The regular meeting of the Schenectady chapter was held Tuesday, June 16, when the speaker of the evening was P. A. E. Armstrong, vice

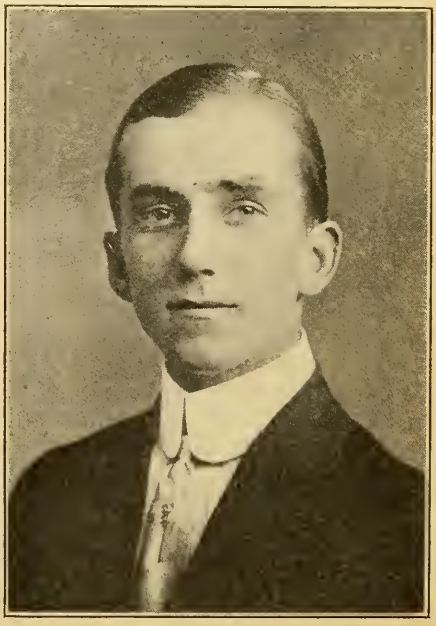
L. A. DANSE
Elected Chairman of Detroit Chapter

W. R. CHAPIN
As Chairman of Indianapolis Executive Committee, He is Directing Plans for the Convention, Sept. 19-24

president of the Ludlum Steel Company. The Schenectady Union Star has the following account of the meeting:

"A meeting of Schenectady Chapter, American Society for Steel Treating, was held last evening in the Civil Engineering building, Union College. P. A. E. Armstrong, vice president of the Ludlum Steel Company, Watervliet, gave a talk on "New Methods for Production of Hollow Drill Steel." He sketched the development of tool steel and mentioned difficulties which had to be overcome. He explained the effect resulting by the addition of tungsten, chromium and vanadium to steel, for tool purposes, and emphasized the importance, when specifying the composition desired, of giving careful consideration to the requirements of actual working conditions to which the tools will be subjected, in service. Following the lecture, many questions were asked Mr. Armstrong, re-

H. C. GOODWILL
Elected Chairman New Haven Chapter



WALTER G. AURAND
Elected Secretary-Treasurer New Haven Chapter

sulting in interesting discussions. As Mr. Armstrong is one of the foremost tool steel experts in the country his remarks were especially interesting and instructive.

"A quartette composed of John Gray, first tenor; Belmont Magill, second tenor; Cyril Cadeau, baritone, and Doc Dillenbeck, basso, rendered several popular selections and received much applause. Chauncey Gray was the accompanist. Mr. Schauffler, Union College, related some very entertaining stories and a motion picture was shown.

"E. J. Edwards, engineer of tests, American Locomotive Company; Carl L. Ipsen, designing engineer, General Electric Company, and G. R. Brophy, metallurgist, General Electric Company, were chosen as delegates for the national convention of the society which takes place in Indianapolis, Ind., next September.

"The Schenectady chapter is planning to have a picnic in August at the Locomotive Club."

NORTH WEST CHAPTER

In addition to the officers of the North West Chapter published in the June issue of TRANSACTIONS, other officers are as follows: Chairman, Prof. Oscar Harder, instructor in metallurgy, University of Minnesota; vice chairman, H. Kenneth Briggs, metallurgist, Minneapolis Electric Steel Castings Co.; secretary-treasurer, Alexis Caswell, secretary of Manufacturers' Club of Minneapolis. The following members of the executive committee were elected: Ralph Dowdell, University of Minnesota; J. C. Irwin, Thexton Mfg. Co.; W. E. Johnston, Mahr Mfg. Co.; C. S. Moody, Minneapolis Steel & Machinery Co.; N. H. Plouff, Emerson-Brantingham Co.

LEHIGH VALLEY CHAPTER

The June meeting of the chapter was held in the Battery Building of the Bethlehem Steel Co.'s plant, on Monday, June 6. The honor guest of the evening was J. E. Howard, engineer physicist of the Interstate Commerce Commission, Bureau of Safety. Mr. Howard presented a paper on the "Relations Between the Physicial Properties of Steel and Their Endurance of Service Stresses". About 100 attended this meeting and thoroughly enjoyed the discussion.

BALTIMORE CHAPTER

D. K. Bullens, well known author and consulting metallurgist of Philadelphia, was the principal speaker at the meeting of the Baltimore chapter on May 24. Mr. Bullens presented an interesting discussion on the "Problems of Heat Treating" and the meeting was enjoyed by those present. The annual election of officers resulted in the following selection: Chairman, A. S. Coulter, metallurgist, Crown Cork & Seal Co.; vice chairman, S. W. Morrow, vice president, Reuse Bros. Co.; secretary-treasurer, W. E. Lehr, manager, Mergenthaler Co.; members of the executive committee, Marshall Medwedeff, H. C. Finck, A. H. Warth, H. A. Reitz, A. E. Nissen; chairman of Membership Committee, Harry C. Finck; chairman of Program Committee, A. S. Coulter.

CHARLESTON CHAPTER

About 75 members of the Charleston chapter met in the Kanawha Hotel on June 15 and listened to A. M. Redding, of the Leeds & Northrup Co., who gave an interesting paper on "Pyrometry". Considerable discussion followed the presentation of the paper, and Mr. Redding proved

very accommodating in answering the questions asked relative to this important subject.

WORCESTER CHAPTER

The June meeting of the Worcester chapter was held on June 16 in the building of the National Metal Trades Association, when a very interesting and instructive paper dealing with "The Tool Steel Industry" was presented by Roy C. McKenna, president of the Vanadium Alloy Steel Co. Mr. McKenna is an interesting and entertaining speaker, and handled his subject in a very capable manner, due to his broad experience and valuable research work in the tool steel industry.

PROVIDENCE CHAPTER

At the last meeting of the Providence chapter the following officers were elected for the coming year: Chairman, Arthur H. Annan, superintendent of the Rhode Island Tool Co.; vice chairman, R. S. Staples, metallurgist of the Taft Pierce Mfg. Co.; secretary-treasurer, William H. Hunt, purchasing agent of the Nicholson File Company.

SPRINGFIELD CHAPTER

The Springfield section held its June meeting on the 17th at the Chamber of Commerce rooms. There was no special speaker; the meeting was conducted entirely by the members and their friends, with the object of getting together to become better acquainted with one another, and to discuss problems arising from day to day in the hardening room.

In order to start discussion, Major Bellis, F. J. Evans, of the Surface Combustion Co., E. A. Sanford, metallurgist of the Hendee Mfg. Co., and F. E. Striker, metallurgist of Stevens-Duryea Co., were asked to give short talks. Those in attendance voted the meeting as one of the most interesting ever held.

MILWAUKEE CHAPTER

A very profitable and interesting meeting was held in the Medford Hotel on May 26 when Lt. Col. A. E. White, National President of the Society, made his annual visit of inspection to the chapter. The election of officers was held for the ensuing year, which resulted in the following selection: Chairman, Wells K. Gregg, metallurgist of the Kinite Co.: vice chairman, C. B. Langstroth, metallurgist of the A. O. Smith Corp.: secretary-treasurer, Fred G. Allison, chemist of the George H. Smith Steel Castings Co.

GARY CHAPTER

The June meeting of the Gary chapter was held in the Main office building of the Illinois Steel Co. at Gary on June 21. The talk of the evening was by Henry Brewer, Chicago manager of the Leeds & Northrup Co., and was an illustrated lecture upon the "Hump Method of Heat Treating Tools". The lecture proved especially interesting and was very much enjoyed by those present.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ABBE, Earl C. (M-6), Moore Drop Forging Co., Springfield, Mass.
BARNES, Charles (M-3), 2009 S. 23rd St., Philadelphia, Pa.
BARDWELL, J. P. (M-5), E. T. Ward's Sons, 260 West Street, New York City.
BATE, H. A. (M-4), 36 Grant St., Munhall, Pa.

BEATTY, Isaac N. (M-5), 407 Evans Bldg., Washington, D. C.
BUELL, William C. (A-5), C/O Geo. J. Hagan Co., Pittsburgh, Pa.
CHEETHAM, C. S. (M-5), 1142 Kentucky Ave., Indianapolis, Ind.
DANIELS, Clarence W. (M-6), 5 Montvale Road, Worcester, Mass.
EDELIN, J. W. (M-5), 407 Evans Bldg., Washington, D. C.
EGAN, Grover (M-6), H. H. Franklin Mfg. Co., Syracuse, N. Y.
GRINNELL, A. L. (S-6), 505 Garrick Theater Bldg., Detroit, Mich.
HIGGINS, John W. (M-1), Worcester Pressed Steel Co., Worcester, Mass.
HOPF, Harry W. (M-4), 532 E. 124th St., Cleveland, Ohio.
IRON AND STEEL INSTITUTE, 28 Victoria St., London, S. W. 1, England.
LEWIS, M. M. (M-6), Pacific Block & Forging Co., 224 Spear St., San Francisco, Cal.
LOVEJOY, C. E. (M-5), Case Hardening Service Co., 2281 Scranton Rd., Cleveland, Ohio.
MATTESON, J. R. (M-3), 2449 South 20th St., Philadelphia, Pa.
MATHEWS, Frank R. (M-6), 14 Princeton St., Springfield, Mass.
McCONNELL, R. Hudson (M-5), Ford Motor Co., Rouge Plant, Dearborn, Mich.
MOORE, Harry C. (M-6), 25 Hall Street, West Haven, Conn.
MOWERY, John N. (M-1), Worcester Pressed Steel Co., Worcester, Mass.
MALMQUIST, C. Wm. (M-6), Shelton Tool & Machine Co., Derby, Conn.
NELSON, Holland T. (M-5), Henry Disston & Sons, Tacony, Philadelphia, Pa.
NETHAWAY, Frank R. (M-5), 4845 Concord, Detroit, Mich.
NOBS, F. W. (M-4), Empire Mines, Grass Valley, Cal.
NYLUND, Harry E. (M-3), 2426 South 15th St., Philadelphia, Pa.
OTEY, N. S. (M-3), 1417 Ritner St., Philadelphia, Pa.
PRAY, Alfred R. (M-5), 1725 E. 70th St., Cleveland, Ohio.
REIS, James W. Jr., (M-12), Y. M. C. A., Gary, Ind.
ROGERS, Robert W. (M-5), 5 Rueckert Ave., Baltimore, Md
SCHRAMN, Edward P. (M-4), 4863 Spokane, Detroit, Mich.
SCRIMGEOUR, C. Bailey (S-5), Cyclops Steel Co., 410 Albee Bldg., Washington, D. C.
SEREINSKY, Louis R. (M-3), Standard Brands Tool Steel Co., P. O. Box 413, Indianapolis, Ind.
SMITH, Alex H. (M-5), Crucible Steel Co. of Amer., Park Wks., Pittsburgh, Pa.
SMITH, DuRay Jr. (M-5), 263 Highland Ave., New Kensington, Pa.
SPITTLE, J. E. (M-5), 474 Maloney Ave., Dearborn, Mich.
TAYLOR, C. W. (M-5), 414 7th St. S. E., Washington, D. C.
VAN DYKE, Fred J. (M-5), 3470 Gibson, Detroit, Mich.
WEIGEL, Charles (M-3), Forge Shop, U. S. Navy Yard, Washington, D. C.
WILLETT, John A. (M-4), 5308 Larchmont, Detroit, Mich.
ZETZER, Henry (M-4), 2872 E. 112th St., Cleveland, Ohio.

CHANGES OF ADDRESS

BANGSER, Wm.—from Bancroft Razor Co., Worcester, Mass. to 393 West End St., New York City.
BELLIS, Maj. A. E. (M-11),—from 95 Princeton St., Springfield, Mass. to Bellis Heat Treating Co., Blake & Valley Sts., New Haven, Conn.
BROWN, G. Graham—from Timken Detroit Axle Co., Detroit, Mich. to Hinsdale, N. Y.
CAMPBELL, Chester M.—from 435 Chicago St., to 5052 Grove St., Elgin, Ill.
DAVENPORT, F. E. (M-9),—from 5634 Magnolia Ave., to 4204 Greenview Ave., Chicago, Ill.
DREWES, Chas. H.—from 962 Fourth St., to 823 First St., Milwaukee, Wis.

ELLIS, Shirley G.—from Atlas Crucible Steel Co., 115 Broadway, to 366 Madison Ave., New York City.
GIBSON, L. H. (M-1),—from 3 Fordham St., Jamaica Plain, Mass., to 7 Crestwood Park, Grove Hall, Mass.
GIERYMSKI, Stanley F. (M-11),—from 220 E. Main St., to 322 Washington St., New Britain, Conn.
GOODRICH, M. L. (M-11),—from Massaoit Hotel, Springfield, Mass. to Box 1262, Springfield, Mass.
HORTON, C. T. (J-1),—from 934 E. 76th St., to 13704 Othello Ave., Cleveland, O.
HUNTER, George C.—from P. O. Box 537, New Haven, Conn. to Hotel Huron, Cleveland, O.
HURLEY, Wm. B.—from Willis Ave., to 2935 W. Blvd., Detroit, Mich.
KOTTNAUER, Edward H.—from 1054 Book Bldg., to 1723 Lafayette Blvd., Detroit, Mich.
LARNED, Lieut. Elmer—from 6243 Woodlawn Ave., to 6341 Kimbark Ave., Chicago, Ill.
MILLER, Frederick (M-12),—from 50 Grove St., to 488 Colorado Ave., Bridgeport, Conn.
NASH, E. R.—from 222 Keith St., to E. County Road, P. O. Box 674, Hanford, Cal.
NEEDHAM, L. P.—from 6157 Grand Vista Ave., Pleasant Ridge, Cincinnati, O. to 5 N La Salle St., Chicago, Ill.
NIGHTINGALE, G. V.—from 163 W. Washington St., to Box 262, Chicago, Ill.
OLCOTT, Frank—from 125 Smalley St., to 53 Cottage Place, New Britain, Conn.
PELOT, J. H. (M-3),—from 10 West Church St., Bethlehem, Pa. to Picatiuny Arsenal, Dover, N. J.
PENNEY, Rupert L.—from Winchester Repeating Arms Co., to 54 West Rock Ave., New Haven, Conn.
PUTNAM, Willis S.—from 306 S. Orchard St., Urbana, Ill. to New Salem, Mass.
RING, Chas. N.—from Ohio Steel Fdry. Co., 531 Marion St. to 1020 Brice Ave., Lima, Ohio.
ROOT, H. H.—from 251 Massachusetts Ave., Arlington 74, Mass. to 83 Barnard Ave., Watertown, Mass.
SAUER, Louis J.—from 407 S. Aberdeen St. to 437 N. Racine, Chicago, Ill.
SICARD, Andrew J.—from Ingersoll Rand Co., Athens, Pa. to Sicard Tool Co., 117 Lawrence St., Hackensack, N. J.
SOWDER, Stanley—from American Twist Drill Co., Davenport St. to 6545 2nd St., Detroit, Mich.
SQUIRE, Thos. S.—from 144 Lascellus St., to 911 Walnut Ave., Syracuse, N. Y.
SQUIRES, John—from 518 Yorkshire Highway, Grosse Pointe Park, Detroit, Mich. to 4389 E. Choulear Ave., St. Louis, Mo.
WELCH, S. N.—from 23 Sabin St., Providence, R. I. to Victor Ring Tractor Co., Providence, R. I.
WILKINS, W. A. (M-2),—from 2309 32nd Ave. S. Minneapolis, Minn. to 300 10th Ave. S. Minneapolis, Minn.
WRIGHT, H. C.—from Eastonia Apts. to 1849 Ferry, Easton, Pa.

MAIL RETURNED

GUTHRIE, Robt. G. (M-10), care Whidney Co., 320 S. Jefferson St., Chicago, Ill.
HERRICK, R. L., Baumer Film Co., 6 N. 48th St., New York City.
McFARLAN, J. T., care Standard Parts Co., E. 65th & Central, Cleveland, O.
McINTYRE, F. J., Bay City, Mich.

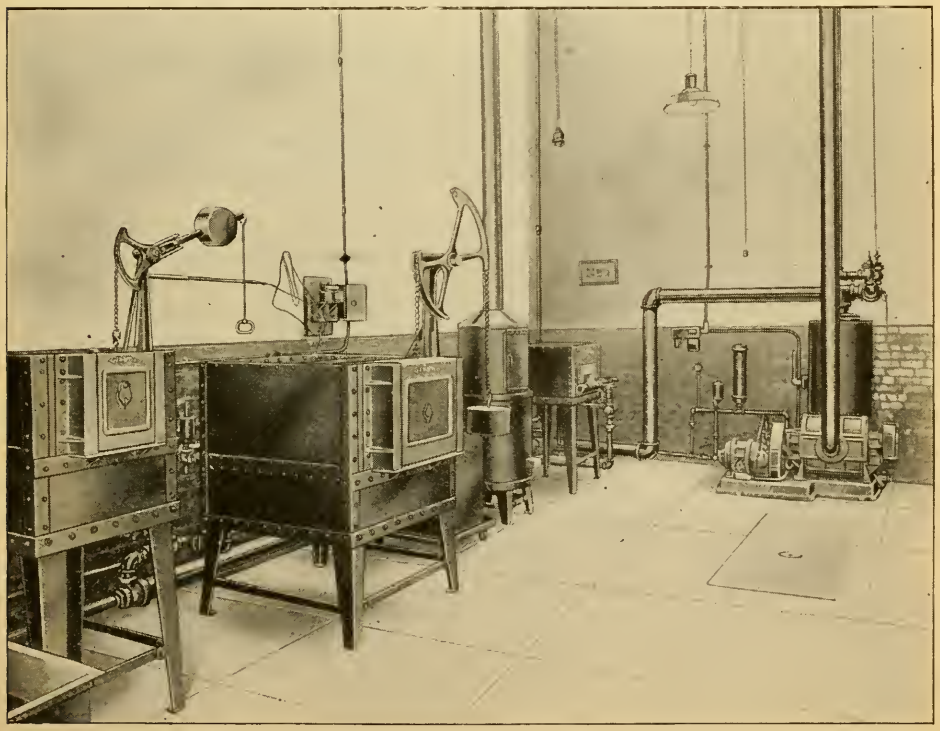
Commercial Items of Interest

EFFICIENT TOOL ROOM OIL BURNING FURNACE INSTALLATION

A large midwestern manufacturer of tanks, pumps, and similar equipment recently has equipped its tool hardening room with a complete oil burning system which is producing very satisfactory results. As this installation is modern in every respect, a brief description is of general interest. The equipment, as shown in the accompanying illustration is installed in a well ventilated room adjacent to the tool department of the plant.

At the extreme left is shown the furnace used for high speed steel work. It is of the semimuffle or oven underfired type. Next in line is a medium sized underfired oven furnace used for case hardening and annealing. The third furnace is a circular cyanide pot furnace used for case hardening small rolls, etc. At the end is a small overfired forge type furnace for tool dressing, etc.

All of these furnaces are constructed of heavy plate steel reinforced with angle irons and bands. In this way the expansion and contraction of the lining does not crack or warp the shell. The linings, with the exception of a few special tile on the smaller sizes, are all constructed of standard fire brick of the best quality. Between the lining and shell a thick layer of insulating cement is used which reduces heat radiation to the minimum.



INSTALLATION OF MODERN OIL BURNING HEAT TREATING EQUIPMENT

The doors are lined with a special cement which is much lighter than fire clay, has greater heat resisting qualities and is more durable. The cyanide pot furnace is fitted with a cast steel pot of a special analysis. This pot seems to give greater life than either the cast iron or pressed steel pots.

Each furnace is fitted with a combination gas and oil burner. In fact, before this installation was made electricity, gas and fuel oil were all considered. Electricity was found to be a very desirable fuel but the cost was much greater than the other fuels and, therefore, would not afford the saving necessary to pay interest on the large investment involved.

Under actual test, 4½ gallons of oil proved to be equal in work produced to 1000 cubic feet of 580 B.t.u. gas. This figured at the rate of 25c for oil as compared to 75c to $1.35 for gas. Therefore, fuel oil is used entirely to fire these furnaces. After making the installation, oil also proved to be just as satisfactory and as easy and clean a fuel to handle as gas, there being no smoke, the fires clean, and temperatures easily and accurately regulated. A very viscous and heavy oil of about 23 degrees Baume is used without heating but even the very small burner on the cyanide pot furnace operated perfectly when burning less than ½ gallon of oil per hour.

The burners are of the open flame type so that practically 40 per cent of the air necessary for combustion is drawn in by induction around the burners, thereby greatly reducing the power required for the blower. These burners are adjustable so that the volume of air may be reduced without reducing the pressure necessary to properly atomize the oil.

The carbonizing furnace is fitted with an automatic temperature control apparatus. This is so arranged that either gas or oil may be burned or both at the same time and the furnace temperatures accurately maintained within certain fixed limits. Even without the use of this apparatus it has been found possible to set the oil burner so that no variation in furnace temperature is noticeable over a period of several hours. This is principally due to the design of the oil burning system which supplies the burners with oil and air.

The oil burning system is designed to supply oil and air to the burners in sufficient volume and under a constant and automatically regulated pressure, free from pulsations; all vital points in the efficient burning of fuel oil. It is of the low pressure type, oil being supplied under a pressure of 5 pounds and air under a pressure of 1½ pounds per square inch.

Clean, fresh air is drawn from out of doors by means of a rotary type blower and discharged into an air receiver and thence goes to the burners. This air receiver is designed with inner and outer tubes so that all pulsations in the air are removed. A mercury pressure gauge and automatic air pressure regulators are fitted to the air receiver so that when one or more burners are closed, the pressure remains constant and it is not necessary to adjust the burners on the remaining furnaces still running.

The oil is drawn from a 550-gallon cylindrical tank buried under the floor by means of a small impeller type pump and discharged to the oil burners. The suction line is fitted with an accessible strainer. The discharge pipe is fitted at the pump with a large air chamber which removes pulsations from the flow of oil, an automatic oil pressure regulator which maintains a constant pressure at each burner whether one or all burners are

in operation, and an oil pressure gauge. At this point a by-pass valve is installed so that all of the oil in the pipe lines may be quickly drained back to the storage tank when desired.

The oil pump is driven by means of chain and sprocket wheels from the shaft of the blower which in turn is driven by means of a direct-geared electric motor on the same bedplate. Co-ordinating the oil and air supply in this way prevents danger of discharging unatomized oil into a hot furnace. A tank gallonage indicator is placed on the wall of the room and shows at a glance the contents of the tank.

Oil is purchased in barrels and the tank is filled through a flush floor waterproof box by means of a special combination skid and barrel drainer. A steel plate is placed in the floor directly over all pipe connections to the tank. Mounted on the wall is a direction board. The air pipes are painted black, oil red, gas green and electric conduit orange. The furnaces, burners, oil burning system, storage tank and quenching tanks were all designed, manufactured and installed in its own plant by the Wayne Oil Tank Pump Co. Fort Wayne, Ind.

The Brown Instrument Co., Philadelphia, manufacturer of instruments for indicating and recording temperatures, pressures, speeds, operations, and drafts, has opened a branch office in Cleveland, at 201 Reliance Bank building, 1634 Euclid avenue. The company now has a total of eleven district offices, located in New York, Pittsburgh, Detroit, Cleveland, Chicago, St. Louis, Denver, Los Angeles, San Francisco and Montreal.

The made-in-Indianapolis industrial exposition the week of Oct. 10 is now assured following the pledging of nearly 100 manufacturers, among whom the trade was prominently represented, to display their products at a meeting recently at the Chamber of Commerce.

H. B. Wilson has taken charge of the Mahr Mfg. Co.'s branch office at 915 Olive street, St. Louis. The company, which manufactures oil burning equipment, maintains its headquarters in Minneapolis.

Electric heat treating and annealing furnaces are described and illustrated in a 16-page illustrated booklet being circulated by Holcroft & Co., Detroit. The furnaces are designed to operate from standard power circuits and are designed along lines of standard construction. The information given in the booklet is interesting and valuable to those whose problems of manufacture include that of heat treating and annealing of either ferrous or nonferrous metals.

F. J. Ryan & Co., Franklin Trust building, Philadelphia, have announced that it recently was awarded a contract for the furnace and burner equipment to be installed at the new plant of the Philadelphia Spring Co. The Philadelphia Spring Co. will manufacture high grade springs for cars, specializing in this work.

Preliminary arrangements for the already existing local sections of national engineering societies in the District of Columbia to merge into a single body were completed by representatives of organizations at a dinner meeting of the Washington chapter of the American Society of

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions. Fee must accompany copy.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

WANTED—Position as assistant hardener. Practical experienced man in case hardening and heat treating of all different makes of steel. Do not claim to be an expert but can deliver the goods. Salary $25.00—$30.00 per week. Address 2-8

WANTED—Position as metallurgical engineer in technical, executive or sales capacity. Ten years practical experience in research, physical and chemical testing, pyrometry, metallographic, inspection, and specifications. Have installed heat treating plants and laboratories. Address 2-5

WANTED—Position as metallurgist or assistant, graduate of University of Minn., one and one half years with large tractor company, covering heat treating, chemical, metallographic and physical testing, during that period. Chicago territory preferred. Salary $175.00 a month. Address 2-6.

WANTED—Position as salesman. Graduate of Carnegie Technical Institute. Student for 16 months with large steel company, Three years selling, Best of references. No preference as to location. Address 2-7

GENERAL SUPERINTENDENT OR PRODUCTION MANAGER—8 years as general superintendent with large manufacturing firm. Expert on manufacturing firm arms and munitions, machinery and small interchangeable parts. Eastern location preferred. Address 4-1.

CHEMIST OR METALLURGIST—6 years as chemist and three years as chief chemist and assistant to the metallurgist. Cleveland location preferred Address 4-2.

SALESMAN—Selling steel or metallurgical supplies. Knowledge of Spanish, Willing to travel. Have been chief metallurgist for large Eastern firm. 7 years experience in heat treating of carbon, alloy and high speed tool steel, and general production work. Experienced in metallography, physical testing, pyrometry, and analysis. Best of references. Address 4-3.

SALESMAN—Have had 6 years in chemical and physical laboratories of tool steel concerns. 3 years in charge of heat treating tool steels. No preference as to location. Wages $175.00 a month. Address 4-4.

FOREMAN OR ASSISTANT FOREMAN—Practical, experienced in all around forging, blacksmithing and treating of steel. Experienced with tools used in shipyards and machine shops. Prefer location in Chester, Pa., Camden, N. J., or Philadelphia, Pa. Address 4-5.

METALLURGIST OR ASSISTANT METALLURGIST—College graduate. At present assistant metallurgist in large motor car company. Capable of handling heat treating, microscopic work, chemical analysis, and pyrometry. Desire Central or Wester location. Salary $250.00 per month. Address 4-6.

METALLURGICAL ENGINEER—Young, capable energetic, with 11 years experience. Graduate engineer. Bureau of Standards for 7½ years. Erie Forge Co. for 3 years. Expert in pyrometry in steel plant, forge shop, open hearth and heat treating plants, metallurgy, investigations and research, planning metallurgical operations, heat treating carbon or alloy steels, and management, forge shop temperature scheduling, etc. Salary desired $3000, or make your proposition. Answer 7-2.

METALLURGIST—Age 25, experienced in manufacture of steel from blast furnace to the finished, heat treated and tested product. Desire to form a connection with company now building up an organization where opportunity at present as the future shall predominate. Cleveland district preferred. Answer 7-3

Superintendent of heat treating—Have had 12 years' experience as blacksmith and in heat treating. At present in charge of same in large automobile plant. Have installed equipment, and have some experience along mechanical lines. During war in charge of aircraft forging, heat treating and as metallurgist. Salary desired $3600. Answer 7-1.

TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, August, 1921 No. 11

BUSINESS PROSPECTS APPEAR BRIGHTER

That business is on the upgrade may be an interpretation of recent trade developments. While these developments are not sufficiently definite to make this statement an assurance, the general tendency seems to point to a gradual revival of industrial activity on a small scale. After months of inactivity, markets particularly in the iron and steel trade are beginning to look up. No one given event or condition can be assigned as a reason for this improvement, but a number of factors working together are exerting a greater or lesser influence on business in general.

Of greatest significance perhaps is the recent announcement of the government that $500,000,000 will be paid to the railroads of the country. That this action on the part of the government will materially strengthen the buying power of the railroads can not be questioned. Practically all of the roads of the country are in narrow financial straits and as a result have almost completely disappeared from the market as buyers. And the volume of business placed by railroads in normal times is considerable. All roads are needing new equipment and extensive repairs for present rolling stock and equipment, but with credit relations already stretched to the limit, further purchases were not to be considered. Thus the government's announcement of intended financial relief came as a welcome to the roads and industry in general and as the relief becomes more certain day by day, the railroads again have begun to place inquiries for materials and even to close on some business which has been hanging fire. Some authorities on economic problems have declared that the return of the railroads to buying would serve as the first step to the resumption of all business and as to how well founded this belief has been is about to be ascertained.

Easing of the financial market during the past few weeks has also served as a stimulant to business and is another factor entering into the complex order of events. Part of the improvement in financial conditions is a result of the sidetracking of the soldiers' bonus bill by the senate together with recent developments in the armament policy of the country and a general economy policy being placed in effect by the administration. Each week shows increase in the reserve ratio of the federal reserve system, the figure standing over 61 per cent compared with a dangerous 43 per cent one year ago. The coming harvest of large and more cheaply produced crops will enable farmers to meet their obligations and to have a good spending power besides.

During the week of July 11, iron and steel markets were somewhat improved over what they had been for some time. While the increase in business was not of large volume, the general tone was better.

Some quantities of goods were purchased and inquiries were placed in larger numbers. Labor gradually is adjusting itself to the new conditions both as regards wages and efficiency, and is exerting some influence in the stabilizing of the present industrial unrest. All in all, indications are that the low point has been reached if not well passed but the developments of the next few weeks must be awaited to prove whether this is actually true.

FATIGUE STUDY OF STEEL IS IMPORTANT

During recent years considerable attention has been given to the fatigue strength of metals or the number of vibrations or repeated stresses which certain parts will withstand before failure will occur. Data upon this subject is of great importance to engineers and builders of machinery and equipment in order that human life will not be endangered by sudden failure of highly stressed parts. Elevator cables, bridge members and automobile and airplane parts are properly classified under this head. Crystallization of the metal has been assigned as a frequent cause of failure but scientific research has proved this conception to be incorrect. In a study of fatigue strength, the problem must be attacked from several angles including the composition of the steel and the relation to heat treatment.

On other pages of this issue appears a comprehensive discussion of the effect of heat treatment on the fatigue strength of steel. In this particular series of investigations the parts tested were automobile leaf springs and the material high carbon steel. Although limited to one type of steel and to one product, the results should serve as a guide in undertaking further study of fatigue characteristics. The author draws four main conclusions which might well be emphasized, namely: 1. There is one certain quenching temperature which yields maximum fatigue strength and in the case of high carbon steel, this temperature corresponds closely to the A_{cm} point; 2 The drawing temperature has a decided effect on the fatigue strength and there is one drawing temperature which yields maximum fatigue strength; 3. Experimental evidence strongly indicates that decarburization has a very detrimental effect on fatigue strength; and 4. Duplication of the regular heat treatment will not cure fatigue but on the contrary will hasten failure of such parts that have already been subjected to repeated stresses.

These conclusions, which were made as a result of extensive work are brief but definite and add to the knowledge of fatigue phenomena. They should pave the way for research as to what may be expected from the many types of alloy steel.

REDUCED RATES TO INDIANAPOLIS

We are very glad to announce that the railroads of the country, through the Central Passenger Association, have granted fare and a half round trip for members of the Society and their dependents, for the Indianapolis Convention and Exhibition, Sept. 19 to 24. A large number of members and guests are always in attendance at this Convention, thus the railroads unanimously decided to recognize the Society to the extent of granting the fare and a half for the round trip.

There are certain restrictions placed on the purchase of these tickets inasmuch as an identification must be presented to the ticket agent for the

purchase of the round trip ticket. This identification certificate will be mailed to all the members of the Society before the first of September.

HOTELS IN INDIANAPOLIS

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reservations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then take the letter with you to present to the hotel clerk at Indianapolis when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$2.00 up " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$2.50 to $4.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 "	not over $3.50 " "
Haugh Hotel	60 "	" " " " "
Linden Hotel	250 "	" " " " "
Majestic Hotel	59 "	" " " " "
Roosevelt Hotel	187 "	" " " " "
Royal Hotel	85 "	" " " " "

SPORT IN INDIANAPOLIS

George Desautels, chairman of the Entertainment Committee, is planning to have an inter-city tennis tournament, and also an inter-city golf tournament. Any exhibitor, member or guest from the various cities may enter these tournaments. Trophies will be awarded the winning tennis team, and to the best golfer. The course at Highland Golf and Country Club has been secured for the golf tournament. This course represents the sportiest and best in the United States, and it will be a treat to every golfer to try out the excellent course.

Not only will there be prizes for the individuals and teams turning in the lowest score, but there will also be prizes for the dubs. So do not permit the fact that you are no low medal artist prevent you from bringing your golf sticks along and enjoying the game. If you're going to bring your golf sticks and tennis rackets along, communicate with George Desautels, Imperial Drop Forge Co., Indianapolis.

SPACE RESERVED AT INDIANAPOLIS CONVENTION

The latest list of exhibitors whose products will be an exhibition at the convention follows:

Alcorn, Blackhouse Co., electric furnaces in operation 3
Charles Englehard, temperature control and recording instruments in operation 4
Surface Combustion Co. 5
Bristol Co., recording instruments in operation 6
Smith Gas Engineering Co., producer gas machines in operation 7
George J. Hagen Co., oil and gas furnaces in operation 8 9
Westinghouse Elec. & Mfg. Co., electric appliances in operation.....A-B
Brown Instrument Co., recording instruments in operation 17
Midvale Steel & Ordnance Co., operating exhibit of steels 18
Indianapolis Drop Forging Co., forgings in operation 19
Eaton Electric Furnace Co., electric furnaces in operation 20
Calorizing Co. of Pittsburgh, calorizing process in operation 21
Deeds Commercial Laboratories, carbonizing compounds in operation 22
Leeds & Northrup Co., electric furnaces and pyrometers in operation.....36-23
Bausch & Lomb Optical Co., metallographic instruments in operation 24
Tate-Jones Co., Inc., furnaces 25
Armstrong Cork & Insulating Co., insulating materials 27
Taylor Instrument Co., in operation 28
Marschke Mfg. Co., electric grinders and buffers in operation 31
Quigley Furnace Specialties Co., furnace specialties in operation 32
Hoskins Mfg. Co., electric furnaces and recording instruments in operation.. 33
Simonds Mfg. Co., steels and saws in operation 34
General Electric Co., electric furnaces in operation 35
William Ganschow Co., gears 37
Bethlehem Steel Co., steels 57-44
Spencer Turbine Co., blowers in operation 45
Driver Harris Co., alloy pots and boxes 49
Crucible Steel Co. of America, steels 63-51-50
Electric Steel Co. of Indiana, castings 55
Penton Publishing Co., "The Iron Trade Review" 58
Witherow Steel Co., continuous die forming 62
Halcomb Steel Co., steels.....82-69
Atlas Crucible Steel Co., steels 83-70
Bell & Gossett, case hardening materials 74
The Iron Age, publications 75
Deeds & Chapin, "Cinch" cement 81
Case Hardening Service Co., carburizing compounds 87
General Alloys Co., alloy pots and boxes 107-94
Electrical Refractories Co., refractory materials 95
W. S. Rockwell Co., oil and gas furnace 99
Electric Alloy Steel Co., alloy steels 100
Colonial Steel Co., steels 108
Herman A. Holz, Inc., metallurgical equipment 119
Bureau of Standards, research work 124
Imperial Drop Forging Co., forgings 120
Vanadium Alloy Steel Co., steels 125
Heppenstall Knife & Forge Co., die blocks 126
E. C. Atkins Mfg. Co., metal saws and cutting machines 153
Mahr. Mfg. Co., furnaces .....Unassigned
Dearborn Chemical Co., oils and rust preventatives .....Unassigned
Central Steel Co., alloy steel 38
Celite Products Co., insulating materials in operation 39
Wilson-Maculen Co. 41

EFFECT OF HEAT TREATMENT ON THE FATIGUE-STRENGTH OF STEEL

By E. P. Stenger* and B. H. Stenger**

(A Paper Presented at Philadelphia Convention)

In the engineering profession, it is a commonly known fact, that metallic parts subjected to vibratory or repeated stresses often fail due to the phenomenon of fatigue or "crystallization", as it is sometimes incorrectly termed. All are familiar with the manner in which a lad without plyers breaks a piece of ordinary soft wire. He will bend it back and forth until finally the wire breaks at the point of highest stress. This is a fatigue failure. In this case, however, the stress induced by bending is high, while the fatigue strength of the material is low, therefore only a small number of reversals are necessary to cause breakage.

By fatigue strength is meant the resistance that a metal offers to alternating or repeated stresses. The endurance of one metal as compared to another, or of the same metal when differently treated, has been found to vary greatly. By some authorities the numerical value of the fatigue strength has been taken to mean the stress at which an infinite number of repetitions does not cause failure; by others it is taken as a comparative figure representing the number of repetitions required to produce failure at a given stress. Throughout this paper the term fatigue stength is used in the latter sense. The object of this paper was to determine the effect which heat treatment exerts on the fatigue strength of steel and the work was carried out in connection with practical problems arising in the design, manufacture, and use of automobile leaf springs.

In practice many parts are subjected to repeated or alternating stresses, but these stresses are in general comparatively low and when the material is of proper quality many million, and sometimes billions, of repetitions are necessary to cause failure. In automotive vehicles, parts such as the steering lever, spindle, springs, frame, crankshaft, piston rod, etc., are subjected to repeated stresses and failure of these parts is often due to fatigue. On steam locomotives such parts as the driving axle, crank pin, connecting rod, etc., are subjected to fatigue stresses. Many other parts such as shafting, elevator cables, bridge members and in general all objects which carry live loads of high amplitude are likewise subjected to repeated stresses and sometimes fail for this reason.

Failures through fatigue generally occur suddenly and without warning and are therefore of the most dangerous character. Such failures, under normal stress, show no deformation at the break and in this and the preceding respect resemble those occurring in brittle material. Indeed, according to Bielby's theory, a hard brittle amorphous material forms in the planes of slip which are produced within the crystals by repeated stresses. Many excellent chapters have been written by Howe, Moore, Bairstow, Rosenhain and others describing the minute and microscopic internal changes which take place within the metallic crystals while undergoing repeated stresses, and therefore, this phase of the subject will herein receive little consideration. Attention will be given primarily to quantitative results.

*Metallurgical engineer, Thompson & Black, accountants and engineers, New York and Detroit.

**Metallurgist, Sheldon Axle & Spring Co., Wilkes-Barre, Pa.

Although fatigue failures resembled those occurring in brittle material, a different type of fracture is generally revealed. The fracture of brittle materials, as is commonly known, is clean cut and of a uniform texture, while on the other hand, the fracture of parts failing through fatigue frequently reveal a non-uniform texture as shown in Figs. 2 and 3.

In examining these fractures it is seen that they are made up of two distinct areas; the one revealing an apparently fine grain, the other showing a comparatively coarse grain, thus simulating the fracture which might result from nonuniformity of the quenching temperature. However, if such parts are examined by means of the microscope, it is found that polished and etched specimens reveal a perfectly homogeneous grain structure throughout the whole of the section. Since the areas, which to the naked eye seem to have a refined grain, are found almost invariably at the points of maximum stress, it is thought that this apparently fine-grained material is caused by the grinding action of the debris resulting from the destruction of the previously angular crystals due to the move-

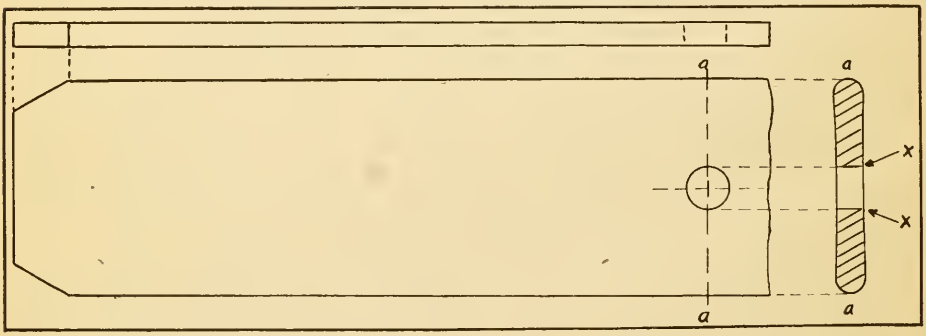


Fig. 1—Sketch of Automobile Spring Leaf Used in Making Tests

ment of the crystallites relative to one another under the action of repeated stresses. These fractures therefore show the absurdity of speaking of such failures as having been due to crystallization. By crystallization is meant the formation or growth of crystals and here it is seen that the action of repeated stresses is to destroy the existing crystals and not to aid in their formation.

Attention is invited to the close similarity existing between the fractures obtained from the laboratory fatigue test and those obtained from service. For instance, comparing fracture *b* to fracture *c*, it is seen that in both cases failure evidently started at the point marked and from there gradually grew until the fissure had spread over the entire fine-grained area, at which time the stress became so highly localized as to cause failure throughout the remainder of the section. There is one difference, however, which is often noted between the failures occurring in service and those obtained in the laboratory test for fatigue. Although in both cases the fissures are seen to grow radially from a central point *Z*, still the service fractures are marked by concentric lines as is most plainly shown in fractures *g* and *h*. It is very probable that these concentric lines are caused by the oft repeated impact blows of small magnitude which are met with in service, while in the laboratory test for fatigue, strength impact is completely lacking.

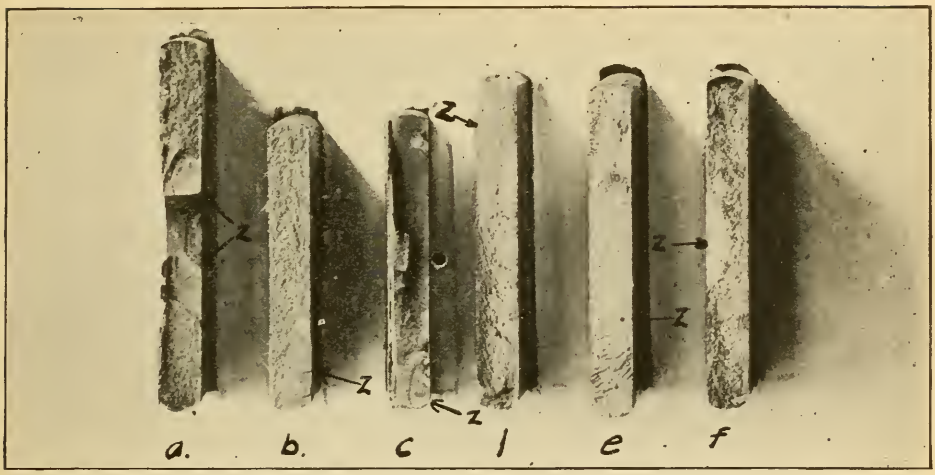


Fig. 2—Fatigue Fractures of Specimens Shown in Fig. 1. (*a*) Leaf Spring Which Failed in Service Showing Fracture through Center-Bolt Hole. (*b*) Carbon Steel Spring Which Failed through Fatigue in Spring Vibratory Machine. (*c*) Chrome-Vanadium Spring Which Failed After Six Months' Service. (*d*) Silico-Manganese Spring Steel After Failure in Laboratory Test for Fatigue Strength. (*e*) and (*f*) Carbon Spring Steel After Failure in Laboratory Test for Fatigue Strength

Before dealing with the influence which heat treatment exerts on fatigue strength, it will be well to review briefly what has been learned concerning this property in the past. Although the first studies of fatigue failures were made over half a century ago and although a great many investigators have devoted much time to problems concerned with the endurance of metals, yet because of length of time required to make the test for fatigue strength and also because of the difficulty of obtaining consistent results, our knowledge concerning the laws governing this phenomenon has made very slow progress.

The earliest and most extensive series of fatigue tests are those made

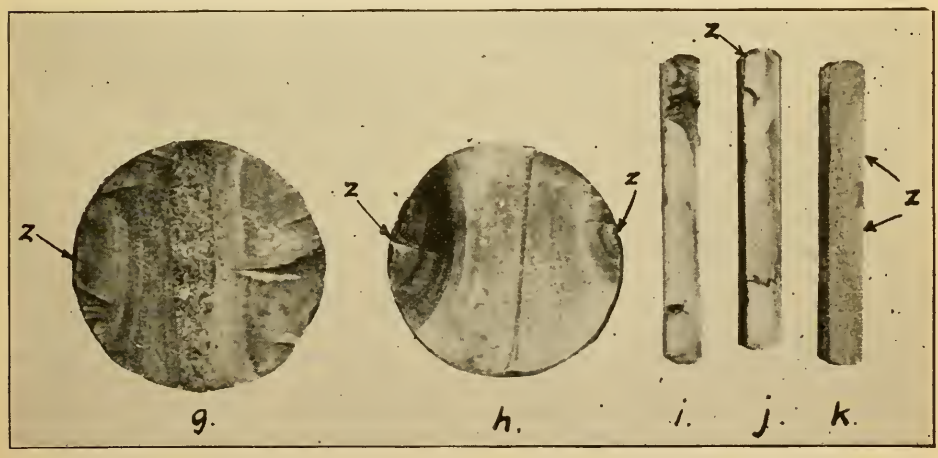


Fig. 3—Illustrations of Fatigue Fractures. (*g*) and (*h*) Chrome-Nickel Steering Levers Taken from Trucks After Failure in Service. (*i*) and (*j*) Chrome-Nickel-Molybdenum Spring Steel After Failure in Laboratory Test for Fatigue Strength. (*k*) Carbon Spring Steel After Failure in Laboratory Test for Fatigue Strength. Dark Spot in Center of Area of Localization is Due to Brinell Impression Made at That Point

by Wohler from 1858 to 1870. His experiments proved that iron and steel eventually will fail at a unit stress much below the ordinarily determined elastic limit if repeated a sufficient number of times. The results of some of Wohler's tests showing the relation between the maximum unit fiber stress and the number of repetitions to cause failure are shown in Fig. 4 in the form of a curve. It is seen from this figure that the number of repetitions to cause failure rapidly increase as the stress becomes lower and that at low stresses approaches infinity. When such data are plotted to logarithmic co-ordinates the curves become very nearly straight lines as is shown in Fig. 5. The special feature to be noted in this figure is that these curves do not change direction at the point where the nominal unit stress is equal to the ordinarily determined elastic limit of the material. By later researches of Upton and Lewis[1] such curves have been found to continue as a straight line almost to the ultimate strength.

Wohler's work also proves that the number of repetitions to produce failure is primarily dependent on the range of stress and not alone on the maximum unit stress. By range of stress is meant algebraic difference between the maximum and minimum stress applied. The range of stress at which the number of repetitions to produce failure becomes infinite is termed the limiting endurance range and this range was found to become more narrow as the maximum unit stress approached the ultimate strength.

Fig. 6, reproduced from Unwin's "Testing of Materials of Construction", shows in diagramatical form the important conclusions concerning the limiting endurance range derived from Wohler's work. Those to whom the figure is not clear are referred to Unwin's book where a good desciption of Wohler's work is given. The work of Wohler was repeated and entirely supported by the later researches of Spangenberg, Bauschinger, Bairstow and several other careful investigators. From his work Bauschinger concluded that under repeated stress the material assumed new and variable elastic limits, the numerical value of which depended upon the nature of the repeated stresses. These limits he termed the "natural" elastic limits as compared to the ordinarily determined elastic limits which he called the "primitive" elastic limits. He then advanced the hypothesis that so long as the range of stress remains within the natural elastic limits failure does not occur, but should the stress range exceed the natural elastic limits then because of the inelastic behavior, work is done, the cumulative effect of which is to produce failure. Later experiments by Bairstow confirmed Bauschinger's hypothesis and it was found by him that the "natural elastic limits" correspond almost exactly with limiting endurance range found by Wohler.

Comparatively recent researches by Stromeyer[2] also lends considerable support to Bauschinger's hypothesis since his results indicate that when the limiting endurance range is not exceeded, no perceptible heating of the specimen takes place. On the other hand, at higher ranges of stress the heat generated was noticeable showing that work was being done.

The work of other investigators indicates that:

1. The fatigue strength is not influenced by the speed of repetitions up to 2,000 reversals per minute. Also that rest and intermittent an-

[1]American Machinist, Oct. 17 and 27, 1912.

[2]Proceedings Royal Society, Vol. A 90, page 411, 1914.

nealing at temperature below the Ac_1 point does not increase the endurance of unhardened steel.

2. Cold rolling increases the fatigue strength while on the other hand cold drawing seems to lower it.

3. Fatigue strength increases with the temperature at which the piece is tested up to between 300 and 400 degrees Cent. and thereafter rapidly falls off.

4. The fatigue strength increases with the carbon content up to eutectoid proportions and thereafter diminishes.

Some of the best authorities are still at variance concerning some of the points enumerated in the foregoing and more research work is needed to prove some of these statements. This holds especially for the effect of overstrain, for instance, No. 2.

The shape of a part or of a structural members has a very important bearing on fatigue strength. This influence, however, is not due primarily to the shape but it is brought about through nonuniform distribution and hence localization of stress. In many cases the formulas now used for calculating stress are very misleading. Their derivation has been based on plain and uniform sections in which the stress is uniformly distributed and for such apply with reasonable accuracy. However, the engineer for lack of any better often applies these formulas to nonuniform sections and irregular shapes in which the stress becomes concentrated at certain points. Holes, sharp corners and sudden changes of outline tend to localize the stress and the actual value at these points is often several hundred per cent greater than is shown by the stress formulas at present used for designing purposes. Therefore the repetitions of stress that such members can withstand are comparatively few in spite of the low nominal unit stress. The researches of Stanton and Bairstow[3] show that the relative values of fatigue strength are about as follows: Rounded fillets, 100; standard screw thread, 70; sharp corners, 50.

In our own experiments with spring steel it was interesting to find that even very slight changes in the shape of the section have most startling effect on the fatigue strength as is clearly shown in Fig. 7. Here it is seen that the center bolt hole reduces the fatigue strength of that section by over 50 per cent. Fig. 1 illustrates a fracture passing through the center bolt hole of a spring leaf which failed in service as a result of fatigue. It shows that the stress becomes localized at the edge of the hole at the point marked *x*. In the laboratory tests conducted on punched plates, an exact duplication of localization of stress occurred at these points. This is the reason why the axle clips of an automobile should constantly be kept tight so that the maximum stress in the spring is made to act at the edge of the spring seat and not permitted to localize at the center bolt hole as it does when the axle clips are loose.

In another case it was found that the fatigue strength was increased several hundred per cent by grinding the concavity out of spring steel as is shown by *C* of Fig. 7. In this sketch the concavity is grossly exaggerated for it is so slight that most persons fail to observe it and assume that spring steel is of rectangular section. Although in the case of *C*, the difference in shape has considerable to do with the increase in fatigue strength, still it is felt that the better conditions of the surface and of the extreme fibers are the paramount factor making for the enormous increase. During heat treatment and previous operations, the ex-

[3]Engineering (London), Vol. 83, page 505, 1907.

treme fibers are often impaired due to the action of the hot gases on the surface. Under repeated stresses the extreme fibers generally fail first and after this occurs, complete rupture soon follows. Therefore, if the extreme fibers are decarburized or otherwise impaired during the heating operations, it follows that the fatigue strength would be greatly reduced. However, the detrimental effects due to such causes can be completely overcome by removing the surface layer through grinding or otherwise, and this is probably the chief reason why *C* of Fig. 7 gave such good results as compared to *B*. What portion of the increase in *C* of Fig. 7 is due to each of the two influencing factors, namely, change of shape and removal of surface layer, will be determined by further experiments.

As yet a completed and systematic study of the effect of heat treatment on the fatigue strength of steel has not been recorded. In reviewing the technical literature, it is found that the data pertaining to this subject are very meager and are of a miscellaneous character representing the results of many investigations in which different methods of testing and different types of testing machines and test specimens were used. It is therefore difficult to properly correlate this data. Gardner, Moore, McAdams and Kommers have performed valuable work in connection with the effect of heat treatment on fatigue and their experiments will be discussed later in connection with the conclusion drawn from our own work.

In the present experiments carbon spring steel was used which had the following composition: Carbon 1.03; manganese 0.45; sulphur, 0.025; phosphorus 0.026. Bars of this steel 18 inches in length, 2 inches wide and about 9/32-inch thick were quenched in oil at 100 degrees Fahr. from 1300, 1400, 1500, 1600 and 1700 degrees Fahr. Test bars quenched at each of the foregoing temperatures were drawn at 450, 600, 800, 850, 900, 950, 1000 and 1050 degrees Fahr. Both tension and fatigue tests were made for every combination of heat treatments, the average of three tests

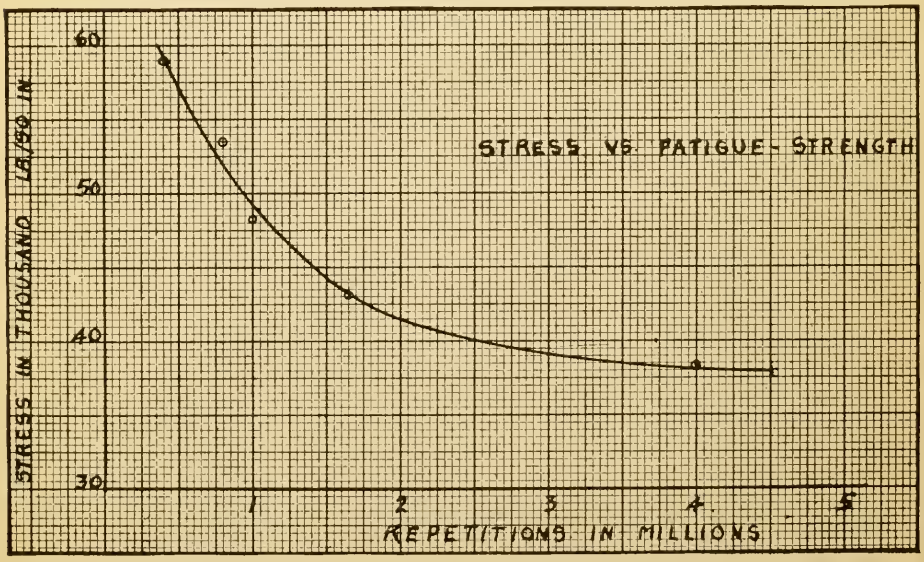


Fig. 4—Fatigue Test on Axle Steel by Wohler

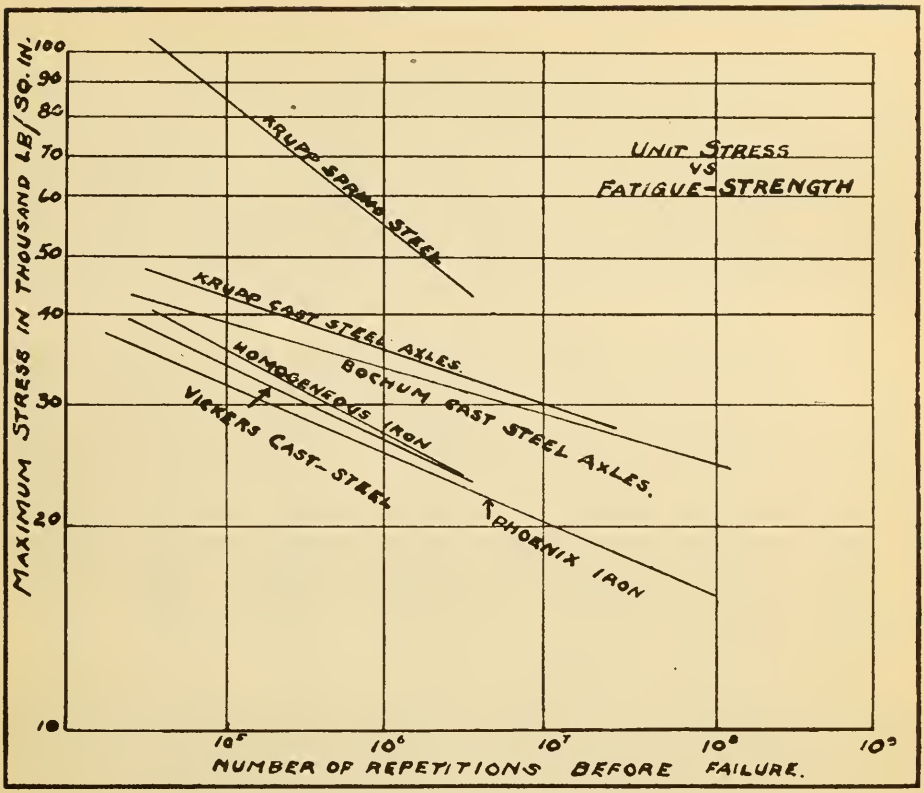


Fig. 5—Wohler's Tests on Various Steels

being used to establish each point. This means that in all a total of 120 fatigue and as many more tensile tests were made.

The heat treatment was carried out carefully in an electric muffle furnace in which the temperature was brought up rather quickly to that desired for quenching. The rate of heating can be judged by the curve taken from the recording pyrometer shown in Fig. 15. The total time in the furnace was about 50 minutes, and the quenching temperature was held for 15 minutes in each case. Three fatigue and three tensile specimens were removed from the furnace and quenched in oil simultaneously by means of a specially constructed rack. The rate of cooling was hastened by agitating the oil by movement of the rack. After the bars had become cold, they were removed from the oil and then carefully heated in the electric muffle furnace to the drawing temperature. Heat treated bars were then carefully ground to size and tested in tension or for fatigue strength. The thickness of the test specimens for the fatigue test was held to within the limits of plus or minus 0.001 inch.

For testing the fatigue strength a vibratory machine was used, in which the nominal unit stress as calculated by the deflection formula fluctuated from 0 to 150,000 pounds per square inch at the rate of 550 times per minute. In this machine the test specimen acts as a cantilever beam, one end being clamped tight while at the other, the load is applied causing deflection in one direction only. The number of repetitions

were obtained by an automatic counter and the end point of the test was easily detected by the loud report emitted by the bar upon failure.

In testing alloy steel it has been noted that failure is not accompanied by noise except in very hard specimens and that it takes place more gradually so that the end point is difficult to determine. If the fractures illustrated in Figs. 2 and 3 are examined, it is seen that the areas of localization in the case of alloy steels cover a larger portion of the section than in the case of carbon steel. Indeed in the case of fracture *h* it is seen that this chromium-nickel steel held to the last fiber. In carbon steel the failure is very abrupt while in the alloy steels the fractures are of a more progressive nature and therefore failure does not occur so suddenly.

The results of this investigation are shown in the form of curves in Figs. 8 to Fig. 14 and in tabular form in Tables I to V. The first figure shows the relation between brinell hardness and heat treatment while the second and third shows the ultimate strength and the yield point versus heat treatment. There is nothing new or uncommon about these tests so they do not require much discussion. However, Fig. 11 shows the relation between the heat treatment and the fatigue strength and should be given close consideration. In these four figures the draw temperature is made the abscissa and the second variable is made the ordinate while the quenching temperatures form the isotherms shown. When the data is plotted in this manner the effect of the draw temperature is most clearly shown.

It is seen from the 1300-degree Fahr. isotherm of Fig. 11 that the drawing temperature does not affect fatigue strength when the quenching temperature is below the Ac_1 point. When the quenching temperature lies between Ac_1 and 1600 degrees Fahr., and the drawing temperature is below 500 degrees Fahr., it is seen that the steel does not offer great resistance to fatigue. This is probably due to the internal stresses set up by hardening and also to the inability of the material to undergo deformation. For the same range of quenching temperature, namely from Ac_1 to 1600 degrees Fahr., a drawing temperature between 600 and 700 degrees Fahr. gives the greatest fatigue strength but on further elevation of the drawing temperature the decrease in fatigue strength is very rapid.

It is seen that a different type of curve results when a quenching temperature of 1700 degrees Fahr. is reached. Two curves are shown for this quenching temperature, the one taking the form of a hyperbola as indicated by the smooth curve shown by the dotted line, the other is drawn so as to more nearly pass through each point as shown by the full line. One reason why it is thought that the 1700 degrees Fahr. curve might be a hyperbola is because one of the bars drawn at 450 degrees Fahr. withstood nearly 8,000,000 repetitions of stress before failure occurred. This is a good indication that the curve becomes parallel with the axis at low drawing temperatures. The bar showing such exceptionally high results was not included in the average for the 1700-degree quench and 450-degree draw heat treatment. When the 1700 degree Fahr. isotherm is drawn as shown by the full line, it somewhat resembles similar curves for some alloy steels and is thought to be the more accurate of the two. It may be that the change in the type of curve is due to the fact that on quenching from 1700 degrees Fahr. invisible hardening cracks are often produced. The fractures of the tensile test specimen quenched at 1700

degrees Fahr. frequently revealed that such hardening cracks were present.

If a large number of fine hardening cracks should transverse the specimen they would be instrumental in lowering the maximum fiber stress far below the calculated value and thus give a fictitious result for fatigue strength. To bring out more clearly the effect which the quenching temperature has on the yield point, ultimate and fatigue strength, data taken from the preceding curves were plotted with the quenching temperature as ordinate, the second variable as abscissa and the draw temperature forming the isotherms. The relation between these variables are shown in Figs. 12, 13, and 14. To avoid confusion, only the higher

TABLE I

CARBON SPRING STEEL QUENCHED AT 1300 DEGREES FAHR.

Temperature deg. Fahr. Draw	Brinell Hardness	No. of repetitions	Ultimate strength pounds per sq. inch	Yield point pounds per sq. inch	Elongation per cent	Reduction in area, per cent
None	269	.....	.....	.....	...	....
480	269	60,100	135,900	71,700	7.81	13.10
600	269	53,210	136,800	65,880	7.98	11.03
800	269	55,900	125,200	68,630	6.64	21.36
850	269	52,190	124,000	66,270	12.17	26.34
900	269	53,820	132,810	73,910	7.62	18.00
950	269	50,350	127,730	67,400	8.52	16.38
1000	269	56,960	136,680	73,180	8.14	13.75
1090	269	58,900	126,000	65,480	12.06	12.53

TABLE II

CARBON SPRING STEEL QUENCHED AT 1400 DEGREES FAHR.

Temperature deg. Fahr. Draw	Brinell Hardness	No. of repetitions	Ultimate strength pounds per sq. inch	Yield point pounds per sq. inch	Elongation per cent	Reduction in area, per cent
None	375	.....	.....	.....	...	...
440	364	104,800	158,460	111,300	0.72	3.00
600	364	110,900	152,430	112,000	1.15	4.35
800	364	102,540	155,700	118,080	0.78	6.68
855	360	88,480	158,100	117,900	2.73	18.07
920	351	106,910	155,000	111,850	1.88	6.50
950	351	67,420	155,200	111,410	1.23	14.43
1000	332	60,300	157,500	106,300	7.56	17.22
1050	311	79,925	150,900	100,610	9.95	20.25

TABLE III

CARBON SPRING STEEL QUENCHED AT 1500 DEGREES FAHR.

Temperature deg. Fahr. Draw	Brinell Hardness	No. of repetitions	Ultimate strength pounds per sq. inch	Yield point pounds per sq. inch	Elongation per cent	Reduction in area, per cent
None	444	.....	.....	.....	...	...
450	444	91,400	183,175	133,150	0.77	2.09
600	444	267,060	203,116	132,466	4.17	12.99
710	444	254,440	.....	.....	...	...
800	430	235,660	202,570	136,900	3.76	15.44
850	418	178,150	196,400	136,030	2.14	4.05
900	402	143,230	195,540	134,660	5.08	18.91
950	387	117,940	185,400	127,000	2.84	5.81
1000	375	110,160	178,800	123,000	3.19	5.30
1050	351	94,520	170,200	109,650	5.79	9.15

TABLE IV
CARBON SPRING STEEL QUENCHED AT 1600 DEGREES FAHR.

Temperature deg. Fahr. Draw	Brinell Hardness	No. of repetitions	Ultimate strength pounds per sq. inch	Yield point pounds per sq. inch	Elongation per cent	Reduction in area, per cent
None	477	.....	.....	.....	...	...
450	512	49,200	.....	137,920	0	0
600	495	172,400	217,517	151,980	2.1	4.8
800	477	141,530	229,066	153,615	8.4	3.8
850	460	102,200	224,600	153,700	8.9	3.9
900	444	97,596	210,766	155,280	4.2	10.4
950	418	77,366	192,860	143,200	5.98	3.0
1000	387	73,766	184,300	133,060	7.04	4.6
1050	375	62,733	173,800	125,880	9.8	5.1

TABLE V
CARBON SPRING STEEL QUENCHED AT 1700 DEGREES FAHR.*

Temperature deg. Fahr. Draw	Brinell Hardness	No. of repetitions	Ultimate strength pounds per sq. inch	Yield point pounds per sq. inch	Elongation per cent	Reduction in area, per cent
None	505	.....	.....	.....	...	...
440	520	272,350 (2)	207,350	161,325	1.26	1.99 (2)
660	509	170,770	222,250	189,650	1.25	1.46 (2)
805	484	86,230	243,700	187,500	3.71	9.88 (1)
850	474	102,080	239,200	176,000	3.71	8.11 (1)
925	457	106,070	212,600	158,800	3.03	6.95 (2)
950	438	91.970	206,800	149,430	4.52	7.69
1000	418	85,216	189,130	133,370	4.81	9.47
1050	387	69,880	187,200	132,700	3.14	11.41 (1)

*About one-third of the specimens quenched at this temperature (1700 degrees Fahr.) showed a hardening crack when tested to destruction. To have some idea of the properties of this quench only specimens free from a hardening crack at point of fracture were included in the summary. The figures in parentheses is the number of tests in average if less than three. The third vibratory bar drawn at 440 degrees Fahr. required 7,962,140 repetitions for failure. Very small area of localization. This bar was omitted from average.

drawing temperatures are shown herewith and these are the temperatures almost invariably used in practice for heat treating parts subjected to repeated stresses. In plotting the curves of Fig. 14, it was assumed that the value of the fatigue strength remained constant for quenching temperatures below the Ac_1 point and that it was equal to that found for the 1300 degree Fahr. quench.

By inspection of this figure it is seen that the quenching temperature as well as the drawing temperature has a marked effect on the fatigue strength and that the maximum values are obtained at quenching temperatures of about 1460-1480 degrees Fahr. which is very close to the A_ecm point of the material in question. It is therefore apparent that for the best fatigue resisting properties the quenching temperature must be just high enough to obliterate the previous existing grain structure. This takes place at the upper critical point, or in hypereutectoid steels at the temperature at which the free cementite is completely taken into solution. If time is allowed, the solution of the cementite will complete itself at temperatures lower than those shown but when the rate of heating is fairly rapid as it was in these experiments or as it ordinarily is in com-

mercial practice, then a temperature somewhat higher than the theoretical A_ecm point must be used to compensate for the lack of time.

Attempts have been made in the past to connect the fatigue strength with the ultimate strength and the yield point but on comparing the curves of Fig. 14 with Figs. 12 and 13, it is seen that the fatigue strength cannot be a function of either of these two properties alone since the quenching temperature affects the ultimate strength and yield point in a manner entirely different from the fatigue strength. As the quenching temperature exceeds the Ac_1 point, the ultimate strength and yield point are seen to increase very rapidly and continue to increase, although at a slower rate at the higher quenching temperatures. On the other hand, the fatigue strength likewise increases rapidly after the quenching temperature passes the Ac_1 point but only continues to increase until the A_ecm point is passed after which there is a sharp decline on further elevation of the quenching temperature.

The type of tensile test specimen used in these tests was that which the American Society for Testing Material recommends for flat steel. Within the gage length, the section is a rectangle of 10 x ¼-inch dimen-

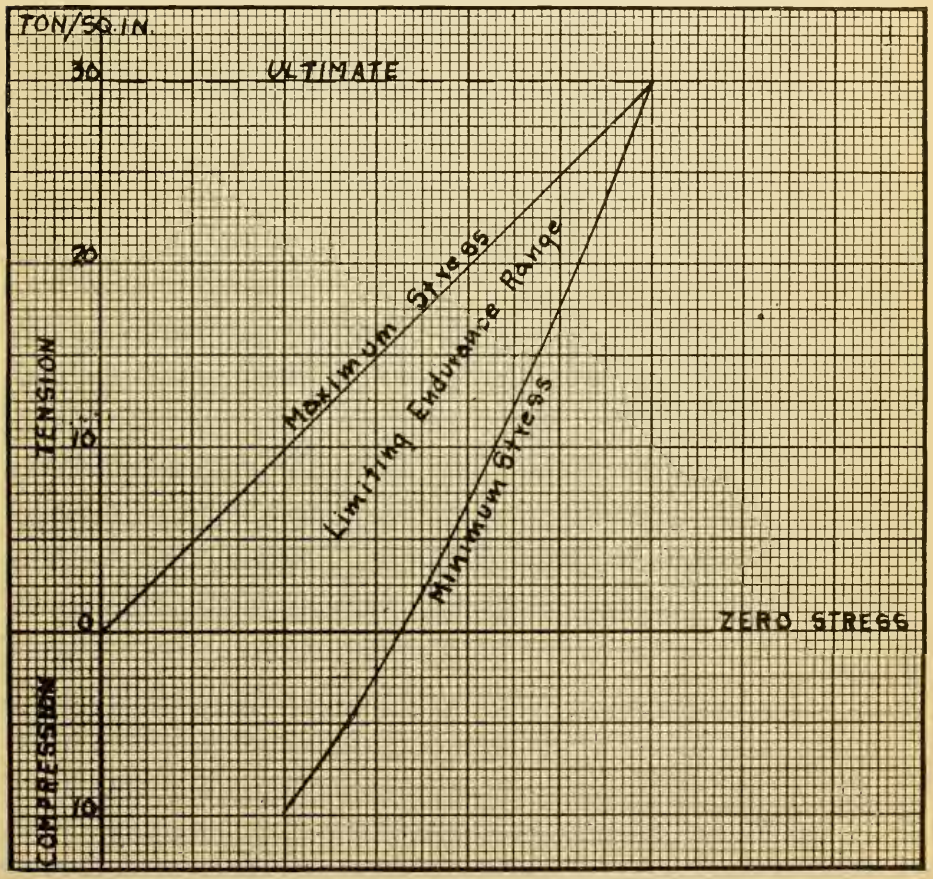


Fig. 6—Range of Stress at Which an Infinite Number of Repetitions Are Necessary to Produce Failure. (From Wohler's Results on Low Carbon Steel)

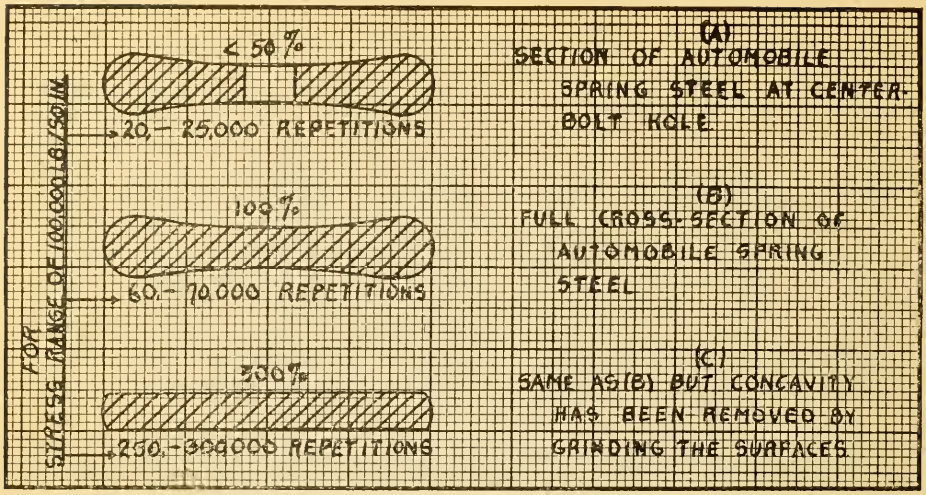


Fig. 7—The Effect of Shape on the Fatigue Strength

sions. This type of test specimen did not give consistent and concordant values for elongation and reduction of area and therefore no curves for these properties were plotted. However, judging from the results that have been obtained from tests made with the standard cylindrical test specimen it appears that these two properties when found in proper combination with the ultimate strength and yield point are fairly good indicators that the quenching temperature has been such as to confer maximum fatigue strength on the steel in question. Of course the heat treatment might be perfect and still the fatigue strength be low. Sometimes foreign inclusions greatly reduce the resistance to fatigue without ap-

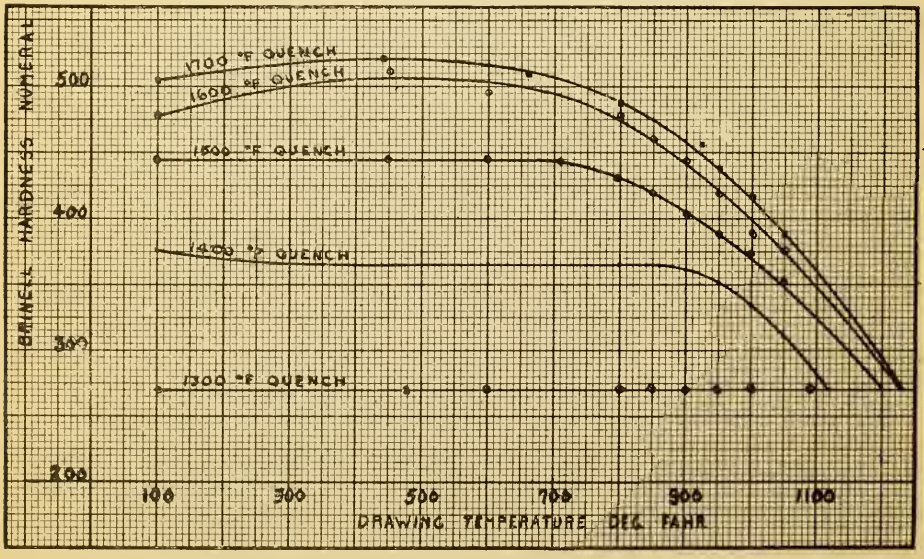


Fig. 8—Brinell Hardness with Relation to Heat Treatment of Carbon Spring Steel

preciably lowering the elongation and reduction of area. Thus it follows that although the physical properties as determined by the tensile test may be instrumental in indicating that heat treatment has been such as to develop the fatigue resisting properties to the fullest extent, still the whole story is not revealed without an actual test of fatigue strength. It is therefore to be regretted that better means have not been found whereby this property can be more quickly and accurately determined.

It will be of interest to compare our conclusions with those arrived

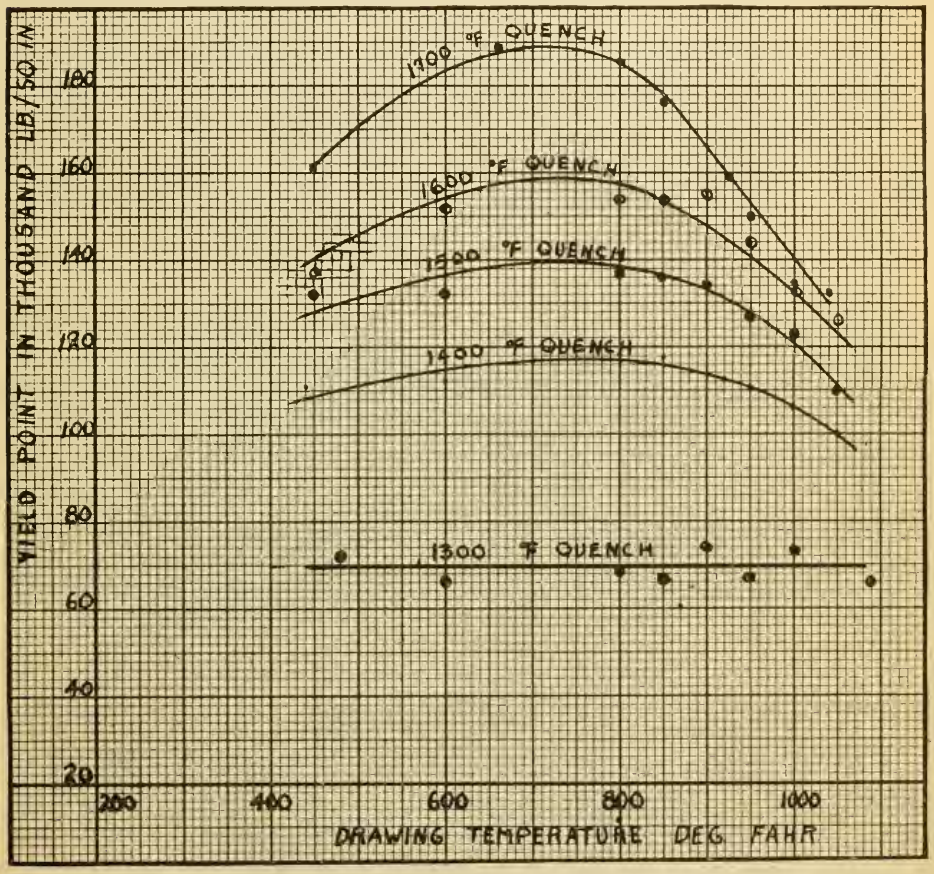


Fig. 9—Yield Point with Relation to Heat Treatment of Carbon Spring Steel

at in prior investigations dealing with the effect of heat treatment on the fatigue strength of steel. McAdams[4] investigated the effect of the drawing temperature on chromium-nickel steel quenched at a constant temperature. His results show that as the draw temperature is lowered from 1300 degrees Fahr., the fatigue strength increases until a point somewhere between 1100 and 1000 degrees Fahr. is reached after which apparently the fatigue strength drops off. It is seen that these results are

[4]Proceedings American Society for Testing Materials, Vol. XVI, Part II, page 292, 1916.

somewhat similar to those obtained in our experiments dealing with carbon steel.

Gardner studied the relation existing between the microstructure and the limiting endurance range of stress. He found that specimens quenched at 850 degrees Cent. gave the maximum results, while a quenching temperature above or below this point caused the limiting range of stress to fall off rapidly. It was concluded by him that the larger the proportion of martensite the greater was the power to withstand repeated stresses. In an account of Gardner's work appearing in the Journal of Iron and Steel Inst. Vol. I, 1905, the kind of the steel used in his experiments is not stated.

Professor Kommers[5] studied the effect of the quenching and drawing temperatures on the fatigue strength of three steels having a carbon content of 0.80, 1.06 and 1.30 per cent respectively. Although it is not pointed out in his conclusions, it can be seen on examining Fig. 5 that the quenching temperature, when followed by a draw temperature above 400 degrees Fahr. has a very marked effect on the resistance of steel to fatigue. Also that the quenching temperature giving maximum results, as in our own experiments, was found to be close to the upper critical point. It was

[5]American Machinist, page 551, April 1, 1915.

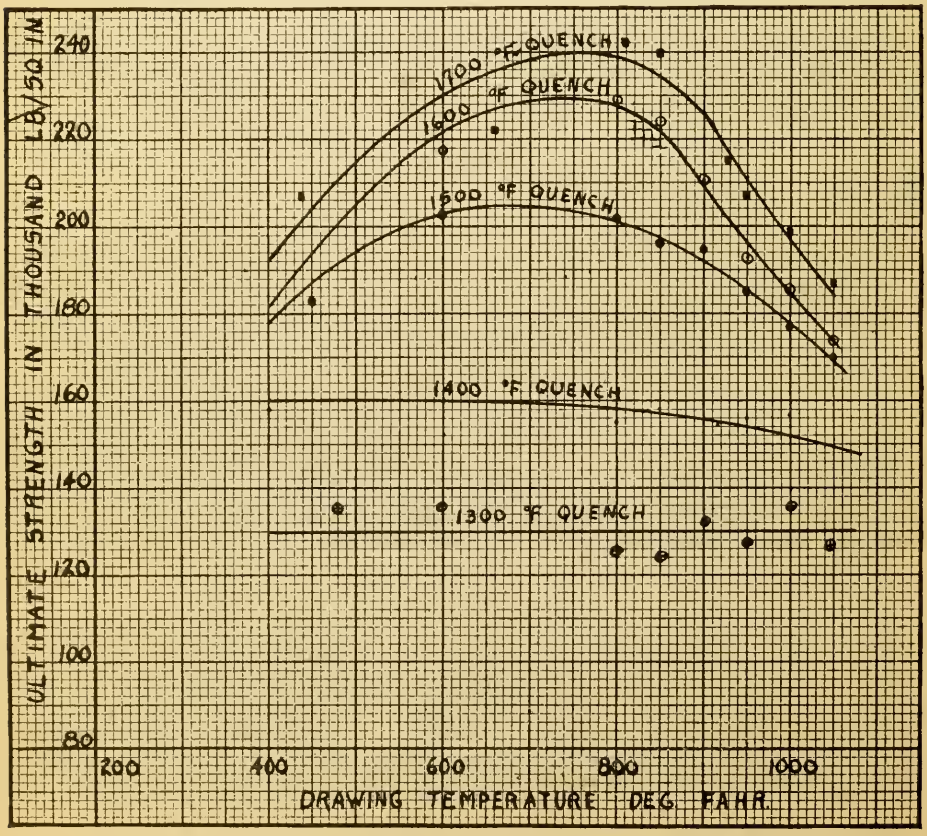


Fig. 10—Ultimate Strength with Relation to Heat Treatment of Carbon Spring Steel

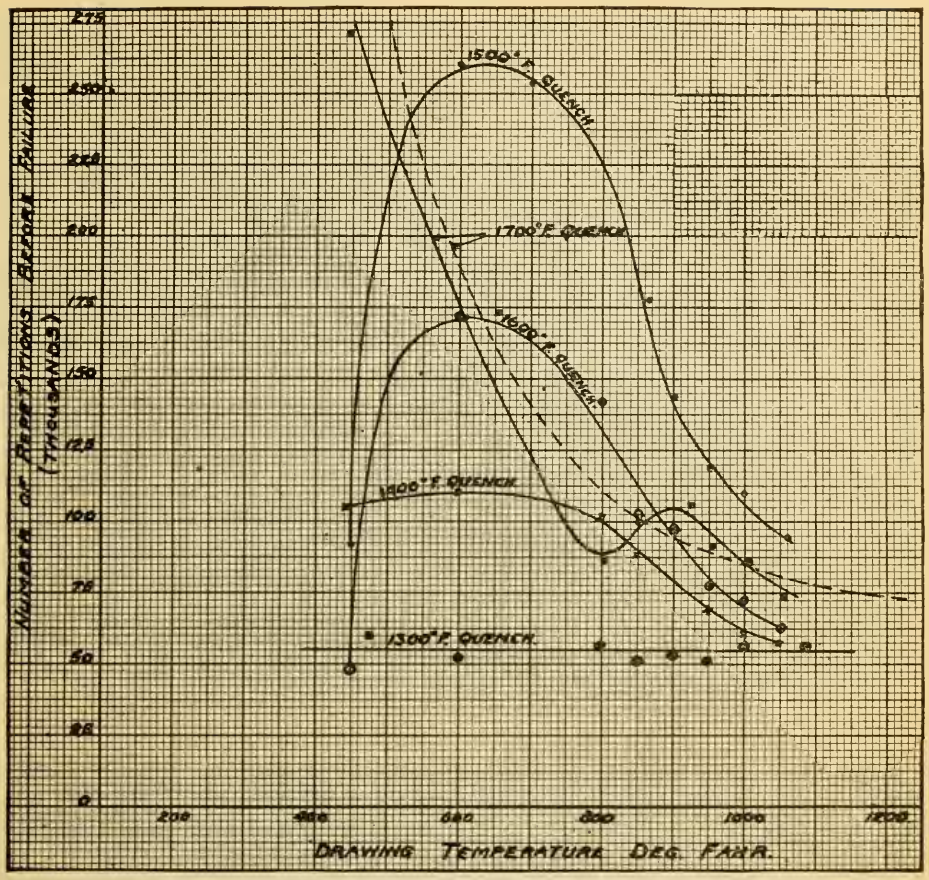


Fig. 11—Fatigue Strength with Relation to Heat Treatment of Carbon Spring Steel. Stress Range 0 to 150,000 Pounds per Square Inch

indeed pleasing to find these similarities existing between the two sets of experiments which were conducted independently and at such a wide variance of maximum fiber stress. The fiber stress in Kommer's experiments must have been very high as the number of repetitions for rupture seldom exceed two thousand. However, Kommer's experiments did not give conclusive results as to the effect of the drawing temperature. In some instances the drawing temperature gave a maximum result at temperatures near to those of Fig. 11, but in other cases the drawing temperature did not seem to have a very decided effect. Kommers concluded that a troostitic structure gives the best fatigue resisting properties. In the present experiments, the specimens having the highest fatigue strength on microscopic examination, likewise revealed a troostic structure.

Since for low values of stress the number of repetitions to produce failure approaches infinity, it follows that the influence of heat treatment in such cases is not so marked as in these experiments where the range of stress is high. In fact, Professor Moore concluded from his experiments[6] that at low stresses nickel and chromium-nickel steel in the annealed condition give higher fatigue strength than specimens of the same steel in

[6]Proceedings American Society for Testing Materials, Vol. XIX, page 206, 1918.

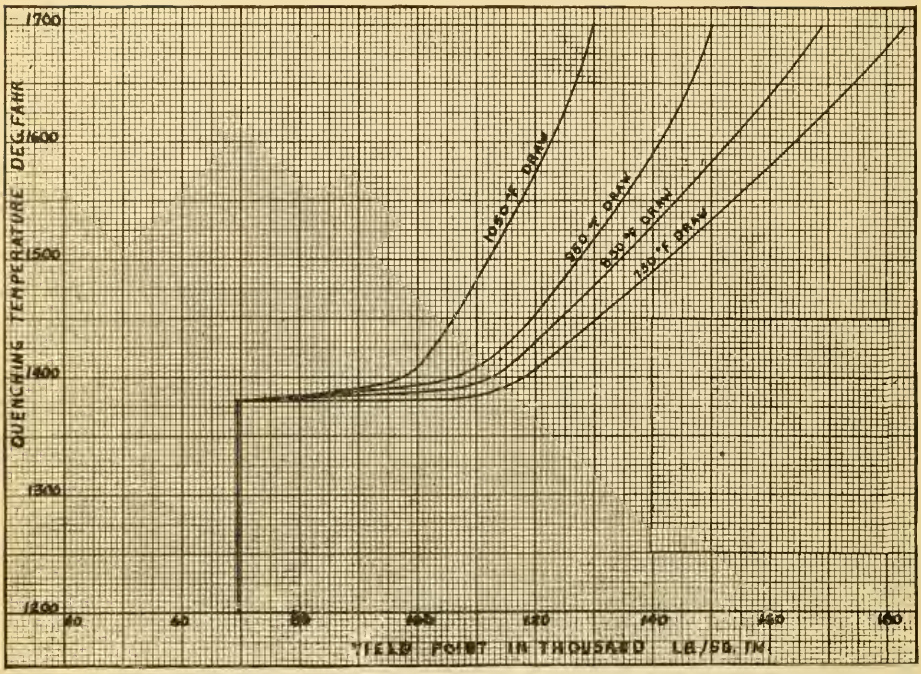


Fig. 12—Yield Point with Relation to Heat Treatment of Carbon Spring Steel

the heat treated condition. On the other hand, Abbot criticizes Professor Moore's statements and from the same experimental data concluded that the heat treated nickel steel shows a fatigue strength about triple that of the same steel in the annealed condition. It is therefore still doubtful as to what extent heat treatment influences the fatigue strength at low stress ranges.

The fact is the heat treater is not deeply concerned with low stress ranges since, as a general rule, only the most highly stressed parts are subjected to heat treatment. In the design of many parts it is often impossible to keep the stress within the limiting range. In such cases the heat treatment is depended upon to increase the number of repetitions which such parts will withstand before failure occurs. Therefore the effect of heat treatment on the fatigue strength at relatively high stresses is of more interest for practical purposes than is the effect which it exerts at stresses within the limiting range.

In the present experiments the range of stress was made equal to 150,000 pounds per square inch and is higher than the stress range ordinarily met in practice. Still the evidence accumulated through the examination of parts failing in service, indicates that heat treatment must have a decided effect on the fatigue strength at such stresses as are ordinarily met in automotive parts. Through the microscopic examination of various chassis parts, of different makes, material, and design which in service had failed through fatigue, it was found that in at least half of such cases the heat treatment had not been proper. Even under poorest conditions, the percentage of defective heat treatment in commercial practice does not

nearly approach so low a figure and therefore it can be concluded that heat treatment has a tremendous influence on the endurance of highly stressed parts.

Another fact met in practice and which is contrary to that expected is the effect which repetition of heat treatment has on steel that has already been subjected to repeated stresses. An example is an automobile leaf spring which has been in service for quite some time. It may become desirable to reshape such springs and this of course must be accompanied with, or followed by, a heat treating operation. If this heat treatment is such as is ordinarily used, it is found that failure will occur very shortly after being put back into service, in fact, in many instances failure occurs during the initial trip. Just why such a heat treatment after the parts have been in service should hasten failure is difficult to see, but that such is the fact cannot be evaded. Of course the secondary heat treatment again changes Bauschinger's "natural" elastic limits and perhaps the metal after once being subjected to oft-repeated stresses loses the power to again assume new "natural" elastic limits, or does so more slowly.

Problems such as these can best be solved by blending the thoughts and experience of the men in the field, the shop and the laboratory. This is what our Society has always attempted to do and it is one of the distinctive features which will make for its success. Our membership is not confined to either shop or technical men and since the views and experience of both are obtained, we should be best prepared to solve such problems as are before us.

Many heat treaters have not had the opportunity to become thoroughly familiar with the phenomenon of fatigue. All the subject matter of

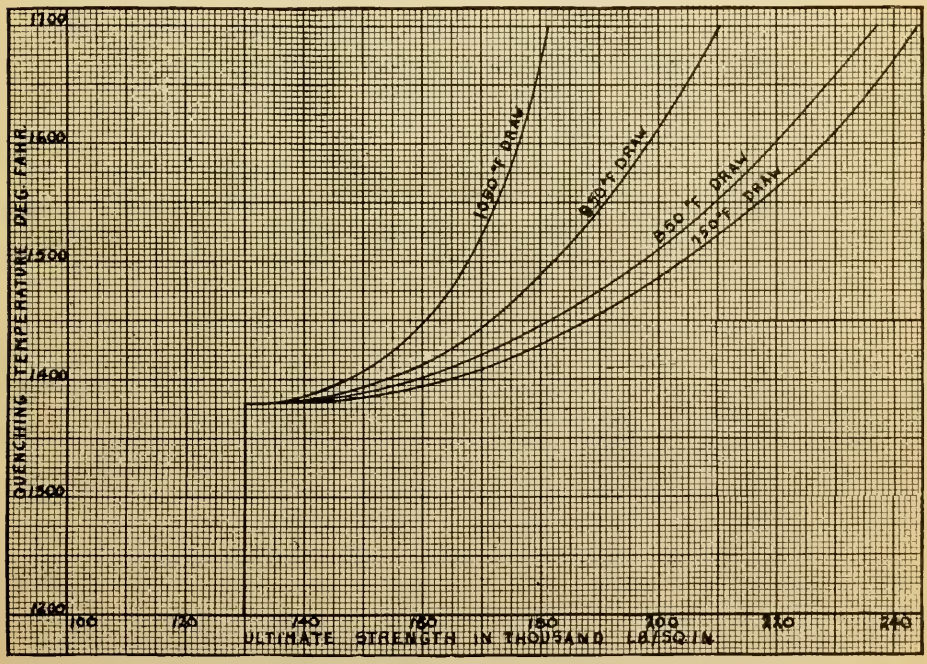


Fig. 13—Ultimate Strength with Relation to Heat Treatment of Carbon Spring Steel

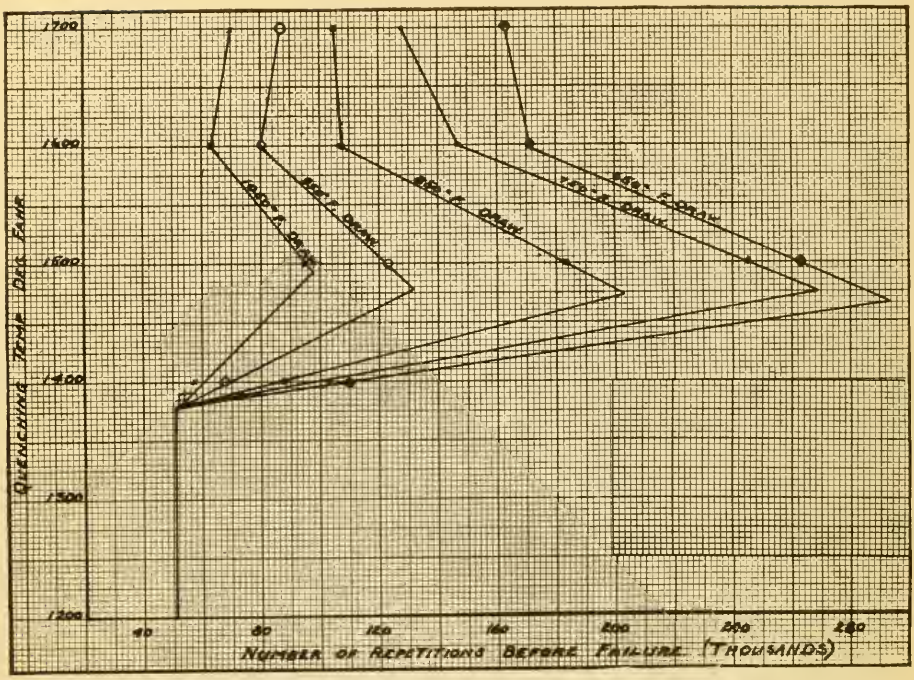


Fig. 14—Fatigue Strength with Relation to Heat Treatment of Carbon Spring Steel. Stress Range 0 to 150,000 Pounds per Square Inch

this necessarily highly compressed paper may not be so clear and explicit as desirable from the standpoint of the lay reader, however, if it is possible to convey to the heat treater, a certain few ideas regarding the effect of heat treating on fatigue strength it will be considered that the time necessary for the preparation of this paper has been well spent. The conclusions may be stated as follows:

1. That there is but one certain quenching temperature which yields maximum fatigue strength and that in the case of high carbon steel, this temperature corresponds closely to the $A_c$cm point. It must be borne in mind that under shop conditions that $A_c$cm point is somewhat higher than that generally given in text books because of the greater rapidity in heating.

2. Likewise the drawing temperature has a decided effect on the fatigue strength and there is one drawing temperature which yields maximum fatigue strength. After this maximum is reached, higher drawing temperatures bring about a rapid lowering of fatigue strength.

3. That experimental evidence strongly indicates that decarburization has a very detrimental effect on fatigue strength and therefore the heat treater should be careful to maintain a neutral or a nonoxidizing atmosphere while heating at the higher temperatures.

4. That duplication of the regular heat treatment will not cure fatigue but on the contrary will hasten failure of such parts that have already been subjected to repeated stresses.

It should be borne in mind that these conclusions hold for high carbon steel and do not necessarily apply to all alloy steels. It is hoped that further investigations will soon be completed which will reveal the rela-

tion existing between heat treatment and the fatigue strength of the alloy steels and since such data are desired by both the engineer and the heat treater, they should be forthcoming at an early date.

Discussion of Paper by E. P. and B. H. Stenger

MR. STENGER: The machine used in this series of experiments was an Olsen machine of the older type. In that machine the test specimen acts as a cantilever beam, that is, one end is clamped in the head of the machine, while the load is applied, at the other end, causing deflection in one direction only. Some of Wohler's early experiments were carried out with a machine which produced both tension and compression of uniform intensity throughout the entire cross section of the test specimen.

MEMBER: Is such a machine superior to the machine you speak of?

MR. STENGER: I do not think so. At least the later experimenters have found that the rotary machine gave much better results, that is, gave more consistent results.

MEMBER: Maximum fiber stresses in the case of a rotating specimen are confined to the surface, whereas in the tensile specimen the fiber stress is uniform. It seems as though the tensile machine would be the better.

MR. STENGER: It would seem so, but the tests made on the two types of machines show that one is about as good as the other as far as getting consistent results is concerned.

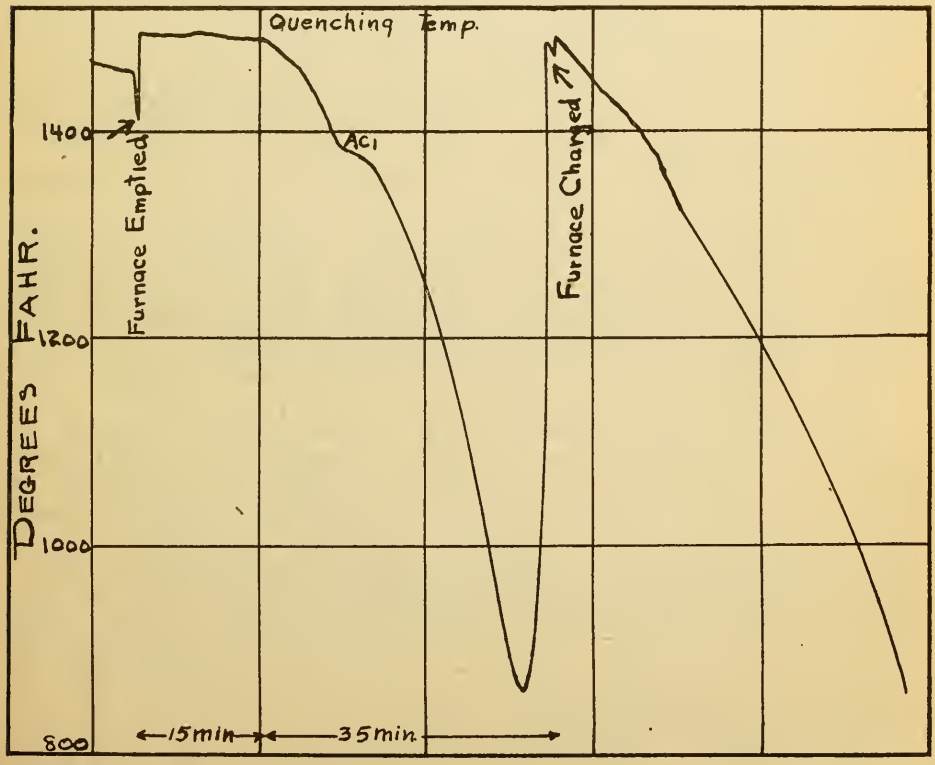


Fig. 15—Curve Which Shows Rate of Heating Specimens Tested

MEMBER: What was the speed of test of the stresses?

MR. STENGER: 550 applications per minute.

MEMBER: What is the reason higher speeds are not used to get quicker results?

MR. STENGER: Higher speeds could be used. There are no objections to using speeds up to 2000 reversals per minute. English experimenters have investigated this point and have concluded that as long as the reversals per minute are below 2000 the results are not affected by the speed. There is no reason why we could not have used a higher speed.

MEMBER: Is it an established fact that the speed has no influence on the result?

MR. STENGER: This has been worked out by careful experimenters and those are the conclusions they have reached, namely, that the speed, so long as it is below 2000 reversals per minute has no effect on the results.

MEMBER: How about higher speeds than that?

MR. STENGER: Higher speeds should give higher fatigue strength. Fatigue failure is the result of slip; amorphous material forms in the plane of the slip and it finally gives way. If the speed is above 2000 reversals per minute the load is applied for such a short time that the maximum effect is not produced at the point of highest stress.

MR. OLSEN: The question of laboratory tests is largely a question of what is to be tested. Where a rotary test might be good for some steels, in certain spring steels it gives no value at all. The test you had, of course, is a logical one for a spring steel.

DR. HARTZELL: I would like to ask regarding the fallacy that still exists as to crystallization. You spoke of slips and fatigue, etc. Can you tell us something about crystallization and why the so-called crystallization does not exist.

MR. STENGER: I would like to have your definition of crystallization first.

DR. HARTZELL: It is simply this: From a study of crystallography we know that the molten magma after solidification increases in size and crystal content, and we have in the steel a mass which was a molten magma. On solidification the crystals are set. Therefore there is no crystal growth after the solidification of the magma.

MR. STENGER: By crystallization is meant the growth of crystals or their increase in size.

DR. HARTZELL: That is true in a liquid, but that liquid is not a solid solution. That is true in course of mobility if the liquid has a slight line of demarcation, as we take an example such as water and oil and so on up into a solid solution like steel. In steel we have a solution but not the liquid. When it is molten we have a fluid mass as we ordinarily understand the term. That fluid mass being made up of a number of chemical compounds which chemically crystallize out as the mass begins to solidify, and before it completes solidification we have a mass of crystals. Crystals are growing according to the temperature; we run the temperature point up and we get the coarse crystals. We may have an iron-manganese compound in which there are crystals, but after solidification there is never any growth.

CHAIRMAN: I believe that is a thing that is pretty well established by former experimenters. Evidently what is a so-called crystalline

break from fatigue is nothing more or less than a condition brought about by mechanical action of the break, whereas the actual microscopic crystalline arrangement remains exactly the same under the conditions after the fracture as it was before.

MR. LYNCH: A few months ago I had occasion to break a number of springs by fatigue methods, working them beyond the elastic limit, and thereby making a few hundred thousand vibrations. After breaking of these test samples, microscopical examinations were made, both near the fracture, within the stress zone, and just beyond the fracture, up in the clamp, where it was not stressed, and I found a decided growth in the microstructure, but in taking successive tests of that kind I found a very decided increase in the microscopic crystal formation or whatever you may call it. On account of the argument being on the other side, I wish to present this as a little experience I have had within the last two months, and it gives a good deal of indication to me there is a grain growth.

MR. STENGER: Mr. Lynch, what was the nature of the fracture? Did it show an area of fine grain material such as the fractures just shown or was it uniform throughout?

MR. LYNCH: The fractures were in every case what is known as a fatigue fracture, starting at the place of maximum stress on the outside of the rod. The tests were all taken on a bar stock. Of course there is a point of maximum stress, and all the fractures started at this point with a very small, fine grain structure at the outside, gradually going across and finally giving way with a fatigue breaking.

MR. STENGER: How would you explain this fine grain structure of which you speak? Have you found crystallization to occur at the same time in adjacent material or in material close by?

MR. LYNCH: When you start your fracture by a stress, you further localize the stresses and go still beyond the elastic limit at that point again until such time as it must fracture there. Regarding the question of grain growth, it did not happen at the fracture, but about ¼ inch from the fracture, and back in the zone that had been stressed hard before the fracture started. It was on account of this high stress, as I took it, that this grain growth had formed, but so far as at the fracture is concerned, I believe that is a localization of stresses, and the repeated increased localization of stresses until the fracture occurred after once being started.

MR. STENGER: Were your experiments carried out on heat treated material?

MR. LYNCH: Yes.

MEMBER: On carbon or alloy steels?

MR. LYNCH: On both.

MR. STENGER: You found the same to take place in both?

DR. HARTZELL: Was that determination macroscopic or microscopic? In other words, was your determination of the crystalline growth based upon a polished and etched section?

MR. LYNCH: Yes.

DR. HARTZELL: Then did you go on, below that to see whether the structure beneath, even a 1/64 inch beneath that, was the same?

MR. LYNCH: I do not quite understand. We simply cut our sample in each case and took the microscopical photograph on the basis of 100 diameters, and we took one photograph only of each spring. We

tapped the surface of the spring all over and we took our photographs half way between the outside and the center in each case. We cut back of the fracture and cut directly across the bar.

DR. HARTZELL: How far from the actual zone of fracture?

MR. LYNCH: About a ¼ inch.

DR. HARTZELL: Then it would be ¼ inch one way and ¼ inch the other way.

MR. LYNCH: It was a peculiar kind of test where I was stressing a considerable portion of my spring.

DR. HARTZEZLL: Had you gone back beyond that you would have found that the original condition of the steel would have given you the same condition of the steel you found under the microscope.

MR. SHONTZ: Do I understand that the gentleman has stressed his steel above the elastic limit? The fatigue test does not usually refer to stresses that go above the elastic limit. Possibly he was getting a deformation there which, polished in a certain direction, made the grains appear to be larger at the point of fracture than they would be back where the steel is not stressed above the elastic limit.

MR. LYNCH: That brings up the question of what is the elastic limit. Some people call the yield point the elastic limit. Is the elastic limit when you pass the point of a straight line and get a curve, or when you reach that point? If you keep below that, of course, some tests can be made, and it is a question of whether you are going to break the specimen or not. If you are truly below your elastic limit our experience has been that little trouble with breakage will result. It is when you go beyond the elastic limit that breakage occurs. I am not speaking of the yield point.

MR. STENGER: You are speaking of the natural elastic limit as described by Bauschinger.

MR. LYNCH: Proportional limit or elastic limit: where they join each other.

CARBURIZING TEMPERATURES BEST SUITED FOR STEELS OF VARIOUS CARBON CONTENTS

By C. A. Haux*

(A Paper Prepared for the Philadelphia Convention)

Certain temperatures give best results for certain purposes. Too high temperatures mean outright failure or poor results at the best. High temperatures, besides producing poor work are expensive on account of the wear on the furnace and carburizing boxes. It is known that pots and boxes will stand up much longer at a temperature, of 1650 degrees Fahr. than at 1800 degrees Fahr.

To find the proper temperature for a certain type of steel one must be governed by; 1, full analysis taken from several pieces of raw material to be carburized; and 2, by past experience. Depending upon memory for past experience would be poor policy; a good record will help wonderfully.

Requirements to obtain best results are dependable help. An honest inexperienced man is better than an experienced man that tries to cover up

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mistakes so that his superior will not find out. A man of this type should not be tolerated within a heat treating plant.

Furnaces must be properly designed and in good working condition. Oil lines, if oil is used for fuel, should have double type strainers. These strainers should be cleaned not less than once every twenty-four hours to secure an even flow of oil. Pipes should be protected from cold or placed near to steam lines to prevent oil from becoming sluggish. Air blowers or turbines must be regulated to the proper pressure. Pyrometers should be used at all times, and a recording pyrometer should be so placed that the foreman can check the heat at any time during the run. Any shortcomings of the above means poor results or failure.

More failures are due to too high temperatures than any other causes. Failures also may be due to poor furnaces or defective pyrometers. In either case, they spell failure. On the other hand, if temperatures are too low, a poor product results from slow and shallow penetration of carbon.

Another item to be taken in consideration is: What are the carburized parts used for? A camshaft needs more careful handling than a piston pin. Are parts ground after heat treatment or are they used without finish? Are they required to stand up under strain, or is a wearing surface the only requirement? With these questions in mind, we proceed to figure proper carburizing temperatures.

The writer has found the following temperatures best suitable for carbon steel.

0.05	to	0.15	per cent	carbon	steel	1700	degrees	Fahr.
0.15	to	0.25	per cent	carbon	steel	1675	degrees	Fahr.
0.20	to	0.30	per cent	carbon	steel	1660	degrees	Fahr.
0.30	to	0.40	per cent	carbon	steel	1650	degrees	Fahr.
0.40	to	0.50	per cent	carbon	steel	1640	degrees	Fahr.

Since these temperatures have been adopted they have been used with but very slight variation and where formerly higher temperatures caused trouble, the above mentioned have given excellent results.

Every heat treater will find a record sheet designed to include all heat treating operation from analyzing of steel to the final test a valuable help. These records will show each individual operation, giving operators name and number, furnace number, pattern number of parts, carburizing material used, and, in fact, a history of the whole proceedings to check back in case trouble should develop.

The record sheet from each indicating pyrometer together with analysis report should be placed on file with the heat treating record. Parts to be carburized can be stamped with a heat number and with the help of a good record can be traced back and further failures avoided.

This paper is not intended as a "cure all", neither does the author believe the temperatures given above are correct for all carbon steels. The analysis of steels should be taken in consideration in each case.

WHAT'S NEW IN METALLURGY

By E. E. Thum*

(Presented before Pittsburgh, Milwaukee and Chicago Chapters)

What's new in metallurgy? What's new in the science and art of producing metals and alloys of excellence from the minerals found in nature? What has happened in the past decade, the last year or two? What are the notable improvemnts just ahead, the trend of the next few years? What influence may the metallurgist be expected to have upon future civilization?

The word metallurgy images to many minds a small, dark, smoky, smelly, iron foundry, or to others a high board fence surrounding furnaces glaring with white heat, and powerful machinery superhuman in power and dexterity. But in its entirety, modern metallurgy influences our civilization down even to the commonest tools of life, and the initiated wonders to what state of savagery we would drop should it become a lost art.

The present has often been called the "age of steel". Our mode of life and material comforts are doubtless the result of a thousand factors, interlinked in a most amazing fashion, yet the influence of the metallurgical and mechanical engineer acting through the iron industry is certainly of great importance, as may be inferred from a brief retrospect of the last century.

One hundred years ago all American pig iron was made in small blast furnaces using charcoal as fuel and having a capacity of 25 to 30 tons per week. This impure, fusible metal was converted into wrought iron in sand-bottomed puddling furnaces of toy-like size, refining perhaps eight tons of metal per week. Hundred-pound lumps of this wrought iron were then taken white hot from the furnace, some impurities squeezed from the mass, and the spongy metal welded into a sound bar by rolling or hammering. Such bars were sold at $100 per ton or more, and was the common metal used by blacksmith, machinist and builder.

Steel, which is essentially an alloy of carbon and iron, was made by the cementation process, packing the best wrought iron bars in charcoal, and heating the containers for days. Carbon was thus absorbed by the metal; the bars were then hammered into shapes for cutlery and other uses where a hard piece of iron was desired. This steel sold at about $160 per ton, and in view of the value of a dollar in those years, could evidently be used only for most precious tools.

Huntsman, an Englishman, had found somewhat earlier that such cemented steel was more fusible than wrought iron and could be melted in a crucible, thus freeing it from undesirable slag inclusions always existing in the original bars. It was more recently discovered by metallurgists that scrap steel, wrought iron and carbon, if simply melted together in a crucible, would make steel; evidently a great measure of economy and a use for waste material. Indeed this is the more common method of making crucible steel at the present time. However, in 1910 crucible steel castings made of scrap steel and pig iron cost at least $45 per ton, or if first quality cemented bar was used the cost was at least $100 per ton. It can be seen that some radical improvement in the metallurgical and mechanical operations

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involved in steelmaking was necessary to reduce the price of steel to a point where it could be used extensively.

The years 1840 to 1850 were eventful to American iron metallurgy, witnessing particularly great improvements in the operation of blast furnaces —those tall shafts wherein a mixture of ore and white hot carbon react to form pig iron, and a waste slag containing most of the nonmetallic impurities. During this time the use of hot air for blast was introduced, coke or anthracite coal replaced the more expensive fuel charcoal, steam power was substituted for water power for forcing into the furnace the air required for combustion, the railways were beginning to develop, at once forming and widening a market for iron and steel products, tremendous beds of high grade hematite ore were discovered near Lake Superior, and the industry started to move toward Pittsburgh, where it would be more centrally located as far as its supplies of raw materials were concerned. All these factors combined to reduce the cost of pig iron, and with it the cost of wrought iron, so that in 1860 puddling costs in America had dropped to a point where rolled iron could be sold for $60 per ton.

Meanwhile in 1856, Bessemer had made his invention of a pneumatic method for the production of steel, and after solving many metallurgical problems incidental to this revolutionary process, it was adopted rapidly. As already noted, wrought iron had hitherto been the material from which steel was made by carburization; wrought iron made by direct reduction of pure ores, or by purification of less pure cast iron in a small puddling furnace.

Bessemer discovered that if cold air were blown through a bath of molten pig iron, the impurities burned away rapidly, leaving the iron and a little carbon behind, and evolving sufficient heat to keep the resulting steel molten, despite its far higher melting point. A ton of liquid steel a minute, rather than a hundred-weight of pasty wrought iron an hour, was the result. Steel was made faster than pig iron could be found to make it from.

The specific influence of the Bessemer process upon prices may be judged from the quotation on steel rails in America. In 1868, before the process was widely used, the price was $160 per ton, while in 1880, when it had been installed in many plants, the price had been reduced to $70 per ton.

About 1880 occurred what was known as the Duquesne Revolution in the iron and steel industry in America, a term denoting the fact that a great many inventions in mechanics, improvements in metallurgy, and changes in the economic system conspired toward a tremendous increase in the efficiency of iron and steel making processes. Cheaply-won hematite ores from the Messabi were beginning to be shipped down the great lakes. Blast furnaces were largely increased in height. Perfecting the hot-blast stove permitted an increased blast temperature, using combustible gases from the furnace top, formerly wasted. Many mechanical improvements were made in the automatic handling of ore at the mine; in loading and unloading on special ore boats; in its storage at the works; and in its selection and charging into the furnace top. Molten iron was taken directly from the blast furnace to the Bessemer converters. Soaking pits were introduced between the steel making department and the rolling mills, so that white-hot ingots of newly cast steel need not be cooled, but their original heat utilized in the working to shape. And finally tremendous improvements were made in the mechanical equipment of the mills for rolling a block-like ingot into a finished

rail, structural shape, bar or plate. The combined effect of these advances may be judged from the fact that they lowered the price of steel rails from $70 in 1880 to $32 in 1890 and $28 in 1910.

The influence on the price and production of pig iron is even more striking. In 1870, 2 million tons of pig iron were made at a cost of $38. In 1880, 3 1-3 million tons were made at a selling price of $26; in 1890 9 million tons at $17 and in 1900, 14½ million tons at $14. In 30 years, 7 times the tonnage at 1-3 the price. The capacity of blast furnaces in the 100 years under review had increased from 25 or 30 tons pig iron per week to as much an hour—200 fold.

Thus, whereas the main structural material a hundred years ago was hammered bar iron capable of sustaining 25,000 pounds per square inch before acquiring a permanent set, and selling at 4c or more per pound, structural steel having a yield point of 40,000 pounds per square inch, is now available in almost unlimited quantities. Consequently, in the intervening time metallurgists and mechanical engineers had offered civilization a huge amount of their most useful building material for 1½c per pound, which a hundred years ago was unattainable at any price and its nearest substitute would have cost in real money at least 6½c a pound for equivalent strength.

In view of this remarkable achievement, what yet remains to be done? Are we, as a blast furnace enthusiast recently put it, "approaching the uniformity of perfection?" Certainly the rate of progress in recent years is marvelous as compared to the lingering two thousand years which elapsed between the invention of the first crude bellows, and its equipment with a simple flap valve. At the present speed, we cannot stop short without wrecking civilization.

The author ventures to say that the developments of the next few years will be an extension of the progress of the last century; that is in getting the most strength for the least money or in the least weight of metal. You recollect that we now use steels instead of weaker wrought iron. That advantage must be pressed. Motor traffic and aviation have demonstrated that lightness in moving parts is no less essential than strength. That great and almost universal disregard of weight instanced in railway rolling stock soon will be a thing of the past, as it becomes increasingly apparent to even the most conservative manager that it takes tons of expensive coal to haul dead weight back and forth across the country to no effect except to wear out good roadbeds.

The easiest rivers have been spanned. The utmost resources of bridge designers have been stopped short at a point where the bridge can safely carry nothing more than its own weight. Yet if only the tension members in a bridge of mild steel could be replaced with another slightly stronger and dependable steel having a yield point of 50,000 pounds per square inch, the limiting cantilever span would be increased from 2000 to 2350 feet.

One naturally expects that alloy steels will fill this need. Past centuries have brought us from the analloyed iron known as wrought iron to steel, pure iron alloyed with carbon. The near future will add a commanding percentage of other metals to this simple alloy. And here the resources of the modern metallurgist are almost limitless and the possibilities almost untouched, even though from an insignificant production in 1910, 7 1-3 million tons of alloy steels were melted in the last 5 years. True, we have known about nickel steels and steels containing high manganese for many years.

More complex alloys have been utilized for armor and armor-piercing projectiles. Some essential properties of tungsten steels have been known for over 50 years—they possess the remarkable property of intense hardness even after slow cooling. Such self-hardening steels were discovered by Robert Mushet between 1860 and 1870, and metalworking tools made from them. Not until the Paris Exposition of 1900, however, did the modern era in tool steel begin; then the American, Frederick W. Taylor, first exhibited the spectacle of a tool cutting so rapidly and deep that it delivered chips of metal at a blue heat and in amazing quantities. Since that time the introduction of modern scientific shop management has been going on apace, wholly made possible by the use of these high speed tools, of steel alloyed with tungsten and chronium, cutting four times as much metal as the best of the older high carbon steels.

Alloy steels containing nickel are notoriously hard to make, and are subject to that mysterious defect called "flakes"—almost unknown in this country until during the war when we needed great tonnages of it for gun tubes, recoil cylinders and breech housings. "Flakes" appear as bright silvery areas in the broken ends of test-bars, which would otherwise possess a mossy or closely granular fracture. Flakes seem not to affect the strength of the metal, but diminish its ductility almost to zero. Their cause was so obscure and their cure so difficult that one of the most prominent and highly respected of American metallurgists, publicly stated that the way to make nickel steel successfully was to leave out the nickel!

Yet Federico Giolitti, an eminent Italian metallurgist, has utilized these same medium-hard nickel steels for the production of heat treated steel castings of such high quality that they replaced forgings on hundreds of field gun mounts made by the Ansaldo Co. for the Allied governments. Bear in mind that castings ordinarily represent the poorest quality in metallic goods, while forgings usually call to mind the most excellent materials. With this difficult alloy, the Italians make castings entirely free of that brittleness and weakness nearly always found in forged, pressed or rolled steels when tested transversely. Castings which withstood the ultimate test with entire satisfaction—the battering of exhausting service in the Great War. Castings lighter than forgings, but equally strong; castings made much more cheaply, rapidly, and with less machine work than the parts they replaced.

Heat treatment has a great share in developing the superior qualities of alloys. The ancient smith who pushed his crude forging into a puddle of water so it could be handled the more quickly, was the first heat treater. Modern industry demands much more precise control of this most important manufacturing step.

With all the resources of the periodic table of chemical elements available for alloying and the infinite combinations of times and temperatures for heating and speeds for cooling, search for new and better mixtures or improvements in old would seem almost as hopeless. Progress would come only by accident and enshrouded with secret practices and worthless nostrums. Fortunately we have another new thing to aid us which has set agog the whole art of getting metals: A systematic study of the physics and chemistry of alloys as influenced by composition and heat treatment, the lusty young science of metallography. Sorby, Martens, Tschernoff, and Brinell were the pioneers in the use of the microscope in the study of metals, but the Frenchman, Osmond, as late as 1888 supplied the key to many metallurgical mysteries by postulating the allotrophy of iron—the idea

that the internal configuration of the iron molecule suffers profound changes, called allotropic modifications, at no less than two different temperature regions. In passing one might remark that iron is by no means the only metal which masquerades in various guises.

It is hardly necessary to offer arguments concerning the importance of the metallographic method to science. Its remarkable growth and widespread use in the shop is sufficient and ample evidence of its value to industry. From a relatively unimportant branch of physical chemistry it has been developed into a means of investigating the properties of metals and alloys on a par with the older methods of chemical and mechanical testing and very frequently solves problems which are inexplicable by the older methods alone.

Physical properties such as hardness, strength, toughness, or magnetism are much more closely related to the minute structure of the material than they are to the percentages of the various elements comprising the alloy. Today no one questions the value of chemical analysis in metallurgical work, but a microscopic examination may be and often has been of far greater value in explaining the properties and predicting the uses of the finished product. The way the various elements combine into chemical compounds, their reactions with each other, the physical properties of the various microconstituents comprising the alloy, their relative size and distribution, the occurrence of impurities, extraneous substances, or "inclusions", and the structural effects of thermal and mechanical treatment are factors we now know to be of supreme importance in determining the properties of the material.

It is in the metallurgy of iron and steel that the metallographic method has found widest application, a natural consequence of the great industrial importance of steel and of the complex nature of the alloy itself. Here iron is extremely magnetic, there almost nonmagnetic; in one form it is brittle as glass; in another almost as ductile and soft as copper; here it is most resilient, there it lies almost as springless and dead as lead; now it is somewhat fusible, then very infusible; here it welds readily, there it can hardly be welded at all; in our files and razors it is extremely hard, in our horseshoe nails it is so soft that the farrier rejects them unless he can bend them on his forehead.

However, there have been found to occur at times profound changes in the strength or hardness, or magnetism of a metal, even solid metal, without any corresponding change in the chemical composition, or indeed any visible change, powerful though the microscope may be. Yet the metal is undoubtedly a different metal; some change in structure must have occurred.

The newest thing in metallography is the study of these ultramicroscopic and even subatomic changes. Difficult though it may be to interpret the realities of things so small as to be utterly beyond our unaided senses of touch and sight, the metallurgist is now facing the still more difficult task of comprehending particles smaller than the wave of light, smaller than the X-ray, even approaching infinite minuteness.

In the complete analysis of metallic structure he is concerned with the ultimate particles of matter—the electron, atom and molecule. It is not sufficient for him merely to recognize that such particles exist and that the atom is an extremely small particle of matter which is the unit of chemical combination. He must ultimately gain some appreciation of the actual sizes of these particles, of their properties, and especially of their relations and

the forces existing between one another. In this way a mental picture can be formed of the construction of metals, and of the mechanism of certain changes in structure which profoundly affect their physical properties and their utility. When this view-point is finally reached, great advances in metallurgy can be directed easily.

How difficult is this feat may be realized when one tries to imagine even the size of such small particles as atoms. Tungsten, for example, which has a specific gravity of slightly over 19, requires about 100 million atoms, as they are normally spaced at room temperature, to make a linear inch. Let us attempt to realize what a 100 millionth of an inch, the diameter of an atom's sphere, is like.

We are in the habit of visualizing all objects in terms of things which we can see with the unaided eye—for instance, we make a map of as large an area as the continent of North America and reduce it to such an extent that we can see its general geographical characteristics on one page or one map. On the other hand, we magnify very small objects to such an extent that we can see their photograph or other physical likeness. Atoms are so minute that it is almost impossible to select a magnification by which this can be done, but let us suppose that we replace atoms by spheres one-hundredths of an inch in diameter—about the size of a particle of pulverized sugar—and let us further suppose that we put as many of these tiny spheres in a row as there would be tungsten atoms in an inch. The row would be 15 miles long! Translating this into volumes is much more difficult, for 3400 cubic miles is something we cannot handle. But if each atom in a cubic inch of tungsten were changed into a grain of pulverized sugar, we could fill Lake Superior with it, or supply a second Niagara for 75 years!

Yet these infinitesimal things, which may be after all nothing more than 99.99 per cent space, and the balance points where the all pervading ether is strained a bit, arrange themselves for the most part in perfect orderly, geometrical fashion when changing from liquid to solid. That much had been inferred from microscopic examination of large assemblages of atoms; it has lately been proved by X-rays reflected by the individual atoms.

Fraunhofer made a so-called diffraction grating by ruling finest scratches on glass, several hundred to the inch. A beam of light falling obliquely on this ruled surface develops beautiful spectral bands of rainbow colors due to the fact that the wave reflected from each succeeding ruling is slightly out of step with its predecessor and causes certain well understood interference effects. When enough of these steps add together to make half a wave length, complete interference and light extinction results. Pure yellow light, for instance, would be reflected as a series of yellow bands of shaded intensities, separated by dark strips, whose spacing, center to center, is a function of the wave length of the light and the closeness of the ruling.

Now if crystals are actually composed of atoms set in regular rows and ranks, it would doubtless act as a diffraction grating, to the right kind of wave motion. True, such rulings are inconceivably fine, but we have available the X-ray for their analysis, and X-rays are 20 thousand times as short as light waves. Following these considerations, it has actually been found that a beam of these waves of known length, reflected from a crystal or mineral to a photographic plate, will develop figures from which not only the distance center to center of atoms may be figured, but their

location in the so-called space-lattice determined as well. The actual structure of a crystal can thus be diagrammed; most metals so far studied have a space lattice similar to a series of cubes, regularly placed, side by side and top and bottom; atoms are located at the corners of these imaginary cubes, and the crystalline system is called cubic. If, as is often the case, there is an additional atom at the center of each face, the cubes are said to be face-centered; if in the geometric center of the cube, body-centered. Investigations of atomic structure have not progressed far enough to furnish many generalizations, but it seems clear that eventually we will arrive at fundamental principles of the utmost usefulness.

We are fairly sure, for instance, that at ordinary temperatures mild steel consists of crystals of pure alpha iron and crystals not of carbon but of a chemical compound between iron and carbon which has been named cementite. Now if this steel is heated to about 900 degrees Cent., the alpha iron changes into another allotropic modification called gamma iron, and the carbide cementite appears to diffuse itself uniformly through the iron—it actually goes into solution, even though the metal is far from its melting point. The resulting solid solution has been called austenite.

Now it is a matter of considerable importance that the mechanism of this action be clearly understood. Carbon may be absorbed by iron in many ways and from many sources—are all the resulting steels alike? Does cementite enter solid solution as a compound and retain its individuality at all times; or does it dissociate into its elements iron and carbon at this relatively low temperature of transformation? X-ray analysis has come to our aid by showing that molecules or compounds do not exist as such in crystalline solids; the unit of organization is the individual atom. For the case in point this amounts to saying that carbon assumes the same position in the austenitic space lattice whether it has been absorbed from graphite, cementite or any carbonaceous compound, and each atom of carbon is held in that position by balanced forces from an unknown but very large number of surrounding particles, both of iron and carbon, and not by the three iron atoms which bind it fast in the compound cementite.

Despite the extraordinary "directional" nature of forces acting between atoms, a force so strong that it is impossible to quench a liquid metal rapidly enough to prevent it solidifying as an aggregate of minute crystalline grains, it is clear that at surfaces separating one crystal from another are located many atoms which are under great stress from crystals on either side, and which do not exactly conform in orientation to any of the atoms about them, and are therefore without crystalline form, literally "amorphous". But this is not the only locus of amorphous metal. We also know that allotropic metals recrystallize when they pass from high temperatures where one phase is stable to a lower, more agreeable to a second modification. Amorphous material apparently cements the smaller and what might be called "secondary" grains of such recrystallized metal. A third occurrence of amorphous metal is found in ductile metals, strained beyond the elastic limit. The so-called permanent set is a result of movements within the crystal itself; the crystals break into blocks, which slide past each other along cleavage planes to new positions of stability, the movement apparently disorganizing several layers of atoms along the slips, producing much noncrystalline or amorphous metal on those planes.

A consideration of the properties of different pure metals, containing various proportions of crystalline and amorphous phases, has established the

conclusion that each phase has a definite and peculiar set of properties. Thus, crystalline matter is relatively soft, ductile and weak, while the same kind of atoms when existing in the amorphous state build up an aggregate which is relatively hard, brittle and strong. Moreover, a crystal will sustain a considerable load in a truly elastic manner—the atoms are pulled slightly further apart, or pushed slightly closer together, but through it all they retain their general configuration and return to the original spacing on release of the load. Heavier loads, less than the ultimate strength, merely cause slip along the cleavage planes—as noted above permanent set ensues, but even yet the load will be supported indefinitely.

I need not dwell upon the importance of these conclusions, so recently formulated as to be among the new things in metallurgy. Extreme fineness in crystalline grain, if it does nothing else, increases the relative amount of amorphous metal in the piece, and imparts a larger share of the special properties of this phase; that is, strength, hardness and brittleness. Although he may not have known the reason for his practice, the smith from time immemorial has endeavored to keep the crystals in his metal as small as possible, by alternate heating, cooling, forging and annealing. Successful heat treatment even today consists in procuring the maximum of the desirable strength with the minimum of the undesirable brittleness, both inherent properties of amorphous steel.

Reverting from this digression to our thoughts on the constitution of that complex substance called metal—a study which is among the newest things in metallurgy—it may be remarked that the phenomenon of hardening still lacks a complete explanation. Why is it that pure iron or copper cannot be usefully hardened, that high carbon steel is glass hard after quenching and soft after slow cooling; that manganese steel is just the opposite—relatively soft after quenching and hard after slow cooling; that duralumin is soft after quenching but becomes progressively harder on resting at room temperature?

There is no time for a critical review of the enormous amount of precise scientific work which has been done on this problem during the last 30 years, nor to examine the various hypotheses which have been advanced. The newest hypothesis, a brilliant conception proposed independently by Jerome Alexander and Zay Jeffries, explains many more of the hitherto unexplainable facts than its predecessors. It may be dubbed the "critical dispersion" theory, and postulates that when a metal or alloy acquires relatively great hardness, it is due to the presence of a second substance dispersed in the original crystals in what might be called a critical size and distribution. This dispersed material may be a pure metal or a compound, but it must be harder than the metal from whence it was born. The particles must be scattered very closely throughout the crystal, and act by interfering with that normal property, the ability to deform by the development of a few large slips, in three ways: first, they prevent the initiation of slip between crystalline layers as would billions of tiny staples in the leaves of a book; next, the slips once started despite this hindrance do not get very far because of the internal friction against the little anchors; and third, the number of slip planes produced by incipient plastic flow, and therefore the absolute amount of hard resisting amorphous material is greatly increased.

Thus the presence of these tiny particles, possibly crystals containing only a few atoms and therefore of ultramicroscopic or colloidal size, hardens and strengthens the metallic grains containing them by increasing the inherent

capacity of a crystal for resisting change under the presence of external force.

Brief mention of the way the theory fits into commonly observed facts in the hardening of high carbon steel will be interesting. At high temperatures the carbon is in solid solution gamma iron—that is, dispersed as atoms. Most drastic quenching prevents any but incipient precipitation, and so maintains an unstable condition little different from the original austenite. The quenched metal is relatively soft.

On quite slow cooling the carbide cementite not only has time to form and precipitate from a large mass of soft ductile alpha iron, but to agglomerate into sizable crystals and plates, appearing under the microscope as "pearlite", well known to metallographers. Notwithstanding the fact that cementite is of itself quite hard, it has accumulated into large crystals which are quite brittle and they themselves crack before presenting effective resistance to crystalline slip in the pure iron matrix under applied stress. The slowly cooled metal is also soft. Therefore, we have extremes in quenching rate, producing extremes in the dispersion of the insoluble constituent, but there is comparatively little difference in the resulting hardness, strength or toughness.

If the quenching is not quite so drastic, however, or if the austenitic metal be given a very gentle anneal—as boiling in water—time and atomic mobility will enable the insoluble and highly dispersed atoms of carbide to accumulate into somewhat larger particles, and strangely enough, maximum hardness ensues. Under the microscope, no separate particles are yet visible; the resulting structure, which has been called martensite, has the regular etch markings characteristic of pure metal or solid solution. The accumulated cementite cannot be seen, yet it offers maximum resistance to crystalline distortion in the surrounding metal.

Further decrease in quenching velocity will allow further accumulation of cementite particles; under the microscope they are still invisible. The appearance after etching is changed and apparently structureless; it has been named troostite. Hardness is reduced somewhat, but the tensile strength is now a maximum. Still slower cooling produces a cloudy structure called sorbite, the accumulation of cementite, though still ultramicroscopic, is then correct for maximum toughness. Here are three well defined stages between the extremes, and one can hardly imagine a more perfect series of phenomena for proving the dependence of physical properties upon degree of dispersion. It is probably true that it has not been proposed before because it is all so simple.

In fact, colloid chemistry, the chemistry and physics of ultramicroscopic particles containing only a few molecules, is a tool whose application to metallurgy is a future step which may confidently be expected to bear rich fruit. Especially will this aid in understanding the diffusion of gases into and through hot or cold metals, weakening the bond between crystals and sometimes causing disastrous and most mysterious explosions; the action of certain alloying elements, such as silicon or titanium, which clear a molten bath of a quantity of gas or slag wholly disproportional to the actual amount added; or again, the great influence which a small amount of other metals has upon the grain size of a casting. If any one yet doubts the practical utility of such submicroscopic investigations, he may be reassured to know that considerations as to colloidal dispersions and intra-atomic forces have pointed the way to quite recent but fundamental improvements in the aluminum industry.

For possible and future uses of what might be suspected of being pure science, it may be pointed out that another way of getting the maximum of strength with the minimum of weight is in super-refining our common alloys, an endeavor which has received all too little attention in recent years. No one yet knows why pig iron from the small cold-blast charcoal furnace makes stronger castings than that from the towering monsters in use today. Again, mild steel with an elastic limit of 45,000 pounds per square inch has had its strength increased 20 per cent after electric refining. The analysis is substantially unchanged, and no difference can be detected in the structure. I venture the prediction that when such riddles are solved, as solved they must be, they will be found to depend upon particles and forces too minute for determination in a test tube, microscope or tension machine.

In ancient years of course only the very purest and richest of ores were used; deposits which might be called bonanzas having been worked up to the present time. Very important deposits are mined in Great Britain containing 90 per cent of ferrous oxide and the balance nearly all moisture, an ore which is naturally very easy to smelt. However the most important British ore in point of tonnage at the present time is the so-called Cleveland ironstone, a ferrous carbonate containing only 33 per cent iron, and high in phosphorus.

The sulphur problem is probably the most important one which must be solved by the iron metallurgist in the near future. Low-sulphur ore and low-sulphur fuel is rapidly becoming exhausted; some sulphur can be eliminated in the blast furnace by running a very basic slag, high in lime, but once sulphur gets in the pig iron it stays there most tenaceously; in fact increased in quantity with each remelting. The basic steel process has eliminated phosphorus, that other enemy of ductile iron, but sulphur control is uncertain at best, and expensive electric furnace refining is now the refuge of the most progressive steel plants and iron founders insisting upon quality metal.

France and Germany also depend almost exclusively upon quite lean ores. The bulk of their iron tonnage is produced from the so-called Minette ore of Lorraine, containing from 27 to 37 per cent iron and up to 2 per cent phosphorus. Some of these ores are high in silica, others high in lime; a mixture can easily be made which can be smelted with little or no additions of material containing no iron, evidently a powerful factor toward making so low grade an ore commercial today.

America is extremely fortunate in having wonderful deposits at the Lake Superior region, from which millions upon millions of tons have been shipped averaging slightly over 61 per cent iron. These ores are low in impurities; while not self fluxing, the amount of waste material is not so large but that the ore is extremely desirable in view of the cheap mining cost. The end of these deposits, however is only a question of time. When that time will be no one is safe in saying, since new developments have so far been able to replace the amount of ore which is carried down the lakes in steamers.

A problem for the future to solve is the utilization of less pure ores now known to exist in the region in huge quantities. In fact that will be the problem before the whole iron trade, no matter where it is situated, in but a comparatively few years. Vast stores of hematites exist in the Lake region, either containing so much moisture or so much clayey earth that they may not be profitably smelted as they are. Already simple drying and washing plants are in operation on these ores. The greater perfection of

these processes and wide adoption will extend the life of the lake ranges many times its present expectance, great though it may be.

Another move in the right direction is being made in the erection of a plant on the end of the Mesabi range, having a capacity of 3000 tons per day, to concentrate the so-called taconite which exists thereabouts in tremendous quantities. This material is a fairly uniform hard rock carrying about 25 to 30 per cent iron as magnetic oxide, which is to be separated from the fine-ground waste material by magnetic separators. The enriched oxide is then mixed with a little fine fuel and sintered into a porous clinker, producing a high-grade, pure ore, especially low in sulphur and excellent for blast furnaces.

When it is remembered that only 40 years ago phosphorus was giving as much trouble as is sulphur today, one might safely predict that before many years the latter can be as closely controlled and eliminated as the former is in the basic process, a process by the way essential for working the most important European deposits—the high-phosphorus Minette and Cleveland ores.

One can hardly predict the successful line of attack. Sulphur may be found to have high affinity for some special slag, more fusible and therefore less costly in fuel than our present ones, high in lime. Or some new ferroalloy may be added to molten steel, eliminating sulphur as ferrosilicon washes out the oxygen. Another interesting possibility, and one which is theoretically sound, is the direct reduction of iron ore to sponge iron by carbon monoxide gas at comparatively low temperature, a heat so low in fact that the sulphur compounds are unreduced and are slagged off in their original state in the subsequent melting, never having entered in the metallic iron.

In view of this history of metallurgy, a history of peculiar dignity, the individual engaged in the art may well wonder what part he may have in its future development. What can one man do with rather limited experimental equipment? The most talked of researches now are the co-operative researches planned on a large scale and requiring the labor of many investigators. The author would like to point out, however, that research cannot be planned, any more than any expedition can be outfitted to locate a new gold lode.

Metallurgists are unabashed in the face of these difficult and important problems in view of the most curious fact that fundamental discoveries are usually made with absurdly meager equipment, not at all in keeping with the magnitude of the subject. The Curies did not need to finger an electron to discover radioactivity—indeed no man or woman ever will. Nor did Newton weigh a planet before announcing the law of gravitation—in fact it is rumored that all he needed was to see an apple fall. Faraday discovered electric induction—the foundation principle of all we know as electrical engineering today—with a magnet and a loop of wire. More recently, Benedicks proved the highly controversial and baffling question of thermoelectric currents in a homogeneous metal by merely cutting a wire in the center and crossing the ends. One may thus well derive inspiration and courage in reflecting on the important work which is possible even with a moderate amount of instrument equipment when reinforced with a large amount of intellectual resource.

Therefore it is rather futile to give instructions to researchers who will find out these real epoch-making things yet hidden. But as a matter of fact, only an infinitesimal number of findings belong to that

class. The rest are merely adaptations of known principles, or an arrival at a given point in well-mapped territory by less devious route. With such utilitarian things most modern seekers are concerned.

Perhaps the principal rule to adopt would be: Don't become discouraged because others have tried and failed. A sufficiently minute search through the literature would doubtless reveal at least one reason why any given scheme would be foolish. One or more men may have actually recorded failures in attempting the same path you plan to follow. But it would be as bad to turn back because some one else had not successfully traveled the route as it would be to abandon the expedition in discouragement on arriving at the first obstacle. Still, don't become discouraged at the wrecks along the way.

Nor do we need to be discouraged because what we find has no apparent utility. Rest assured that each bit of information will eventually be used in the advance of civilization—indeed may be delayed sometimes by its lack. Faraday could not have prophesied the end of his electrical research; no more can we today. Not long ago metallic calcium of high purity was manufactured. It had no apparent use. A considerable industry, however, has since come to depend upon the so-called tungar rectifier, whose principal parts are metallic calcium, a bulb of special glass, a spiral of tungsten wire, an electrode of artificial graphite, and a little argon gas. Twenty years back not one of these essentials was available.

The educated man in metallurgy is, if nothing more, doing yeoman work in the ranks, pushing the art forward. Only a month or more ago, public recognition was given to the graduates of Sheffield University in that English steel center, in view of their indispensible services in keeping that city at the forefront in steel manufacture. But more than this, the metallurgist can keep open the door to information. The secret process is too often old and wasteful—he who keeps out proper inquiry too often keeps out information—and sometimes the manufacturer is ashamed to let the world know he is still nursing obsolete methods.

THE PYROMETER FROM THE STANDPOINT OF THE USER

By Arthur N. Armitage*

(Presented by Title at Philadelphia Convention)

Nearly all the articles dealing with the subject of pyrometers have been written by people who were financially interested in some particular make of instrument, and however impartial they may have tried to be, they have at least failed to mention imperfections or disadvantages to be found in the particular type of installation in which they were interested.

The thermocouple principle is now almost universally employed as a means of measuring heat in the steel industry except for very high temperatures such as the temperature of molten metal in which case, optical pyrometers are used.

All the makes of pyrometers now on the market have their good points, the question is, which kind, if any, is the best for our particular purpose. It is possible that a system which would be satisfactory for use in the ceramic industry would not be of much use for the treatment of steel.

The indicating and recording millivoltmeter perhaps is the simplest

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measuring instrument and the one which requires the least attention from the operator. We now have a single point recorder which requires almost no attention except to keep the clockwork wound up and a little cleaning and oiling when the roll of paper is renewed.

The millivoltmeter employed should be of sufficiently high resistance to take care of the resistance of the lead wire which varies with the temperature to which the lead wire is exposed and also with the length of lead wire used. If the instrument is located near the furnace and compensating lead wires are used, a low resistance instrument can be employed and will give sufficiently accurate readings, but if it is necessary or advisable, as is often the case, to locate the measuring instrument at some distance from the furnace, an instrument of much greater resistance will be necessary to read the true electromotive force of the couple.

A pyrometer system arranged so that couples can be made up at the plant probably is more economical in operation than the one in which the couples must be purchased completely assembled. The different parts, including the time of the operator taken to make up and calibrate the couples, do not cost nearly so much as new couples, and new couples must be calibrated also. The heads can be used repeatedly, then again, couples can be shortened a few inches when the ends become burned off or when the couples are found to be incorrect on checking.

We have an instrument in connection with four coal-fired pit furnaces which was made to be used with shunted couples, and as we often have to run the furnaces at very high temperatures to reach the A_{cm} point in hyper-eutectoid steels, the couples were very easily destroyed and new ones had to be bought.

It was found that cromel-alumel wire had a millivolt-temperature curve that was very similar to that of the couple of the instrument in question. By carefully calibrating the cromel-alumel couple against the couple intended for the instrument, a shunt was made for the millivoltmeter so that correct temperatures were recorded and couples made up at the plant could be used.

These couples would read correctly only between the temperatures of 1550 and 1800 degrees Fahr.; the slight error recorded when the heat was rising and falling was not important. A double throw switch is arranged so that either one of two shunts can be used, one to be used for high temperatures and the other for the draw.

At first some trouble was had in twisting the ends of the wire being used to make up the couples, especially with the No. 8 wire. It was found, however, that by clamping the two wires about ½-inch apart in an ordinary vise with about 1½ inches to be twisted and, after first hammering the wires for the first turn of the twist then holding them with a monkey wrench, a twist could be obtained equal to that of couples received from the factory.

An electric weld is better than an acetylene weld for couples and we are welding our couples by using the rheostat on the optical bench. Disconnecting the wires from the arc lamp, we connect two insulated wires to the rheostat, one of them to the couple and the other to a discarded piece of carbon from the arc lamp. A package of borax completes the outfit and good welds are very easily and quickly obtained.

A single point recording millivoltmeter is used in connection with six drying ovens used for drying molds, and the recorder can be transferred to any one of the six ovens through a six point switch. A prac-

tice has not been made of using recording temperatures at the drying ovens and the instrument is used as an indicator, occasionally, however, the recorder has been used overnight on special work. To do this a recorder instead of an indicator was installed.

At first the firemen were not interested in the pyrometer at the drying ovens but now they swear by it and the molds are thoroughly and uniformly dried. The only occasion for complaint regarding the condition of the molds since the pyrometers were installed was, when the light in the instrument case burned out during the night and the firemen could not see to read the temperatures.

It has been found that when the different pyrometers are kept in order, the operators at the furnaces depend almost entirely on them, which is as it should be, especially on coal-fired furnaces where the physical strength of the operators is the principal requirement. The pit furnaces previously referred to are operated by a gang of huskies who refer to the temperature as so many pounds instead of degrees.

They are given a schedule showing the required temperature at each hour as for example:

10:00 a. m. 1200 degrees Fahr.
11:00 a. m. 1210 degrees Fahr.

In annealing or treating very large forgings or castings, special effort is made to have the hot junction of the couple touching the metal being treated and protected somewhat from the direct flame. For castings such as press cylinders, bare couples are used so that they can be twisted or turned in any desired direction. For instance, a bare couple about 12 feet long is placed with the hot end of the couple inside the cylinder so that temperatures on the inner wall can be obtained. The couple is then covered with wet fire clay along its length to protect it from the flame.

The temperatures at the car type furnaces are recorded on 12-point potentiometer recorders except when we have occasional demands for temperatures higher than 1600 degrees Fahr. In a treatment where temperatures higher than 1600 degrees Fahr. are desired the recorder is run to this point, the couples are then removed from the furnace and the temperatures taken with a pyrometer ball. Our own pyrometer balls are made from wrought iron stock and are very accurate so much so that if there is occasion to doubt the accuracy of a couple during the progress of a heat, a ball is taken at this point. If the couple and the ball do not check, the offending couple is substituted for another.

The potentiometer is undoubtedly the most accurate instrument for measuring temperatures, line resistance can be neglected and closer readings usually can be made. The type of potentiometer provided with a cold junction compensator is very dependable, the only objection being the care required to keep the instruments in working order.

In making up couples of the iron-constantin type, it is desirable to use some kind of powder in the protecting tubes to exclude gases as the couples last much longer when the powder is used. We use dry fireclay and the only trouble experienced was in getting the powder into the pipes. The couple heads of this particular type were evidently designed with the idea of keeping everything out of the pipes but we finally decided to make up some tubes with the hot end threaded instead of plugged. The thermocouple was first inserted by standing the pipe upside down, pouring in the powder and closing the end of the pipe with a pipe-cap.

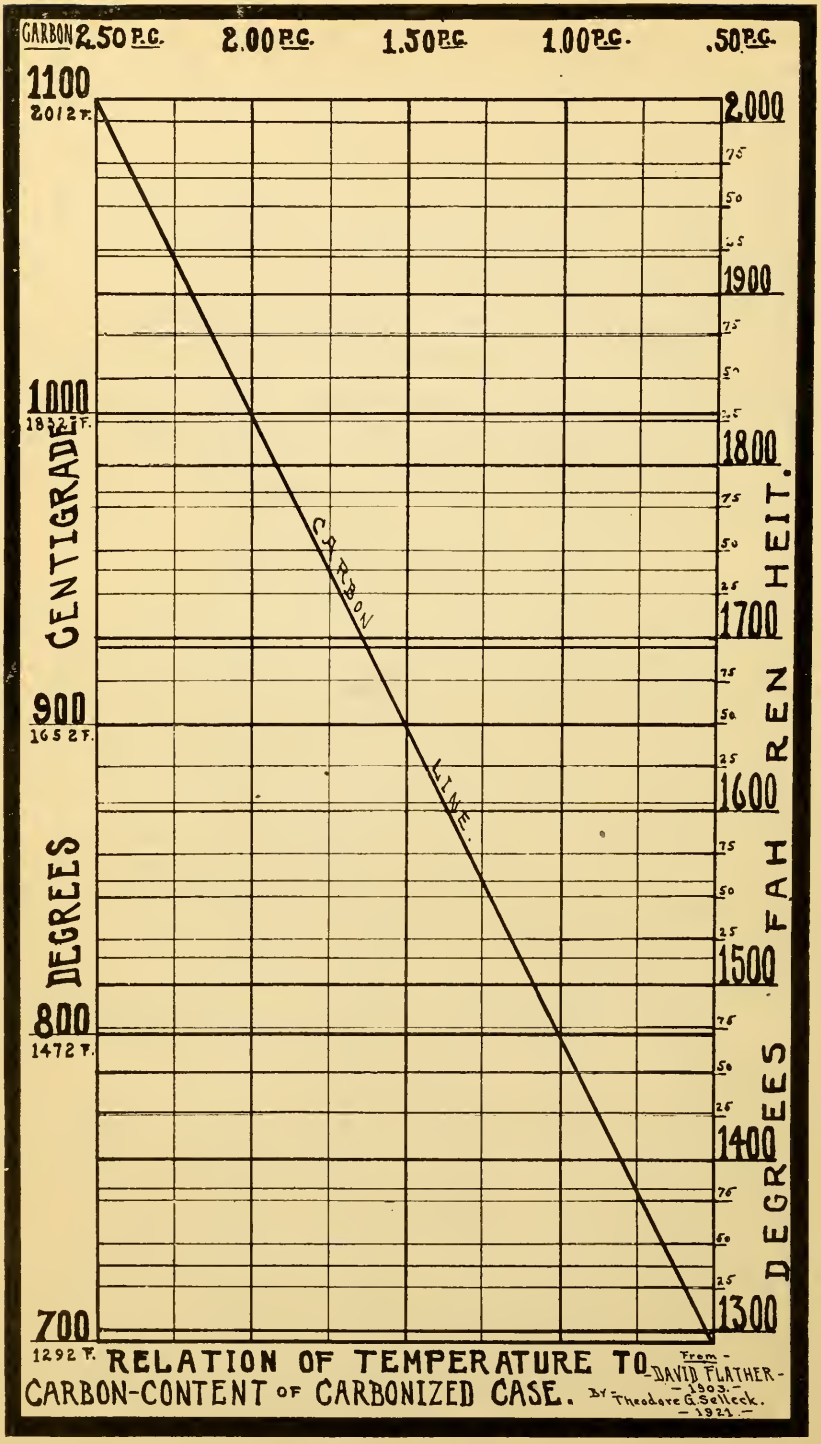
CARBON 2.50 P.C.
2.00 P.C.
1.50 P.C.
1.00 P.C.
.50 P.C.
1100
2012 F.
1000
1832 F.
900
1652 F.
800
1472 F.
700
1292 F.
DEGREES CENTIGRADE
2,000
1900
1800
1700
1600
1500
1400
1300
DEGREES FAHRENHEIT.
CARBON LINE.
RELATION OF TEMPERATURE TO CARBON-CONTENT OF CARBONIZED CASE.
From - DAVID FLATHER - 1903 -
By - Theodore G. Selleck. - 1921 -

Fig. 1

THE CARBONIZING PROCESS—RELATION OF TEMPERATURE TO QUALITY OF CASE AND CORE

By Theodore G. Selleck*

In discussing this subject it is important that we have a clear idea, first of all, as to what is meant by the terms "case" and "core", of carbonized steel, and what their physical and chemical characteristics are.

In all carbonizing operations there is or should be left a portion of the metal in its original condition; that is, a part of the metal is not allowed to carbonize, being prevented from so doing by the shortening of the carbonizing period; hence the steel in that section remains or should remain in the condition it was in before the operation began. Such section of the metal is called the "core", while the carbonized surface is called the "case".

The low carbon core of case hardened steel imparts the ductility necessary to resist breaking strains, while the case furnishes a hard surface for resistance to wear; this combination furnishing parts that combine those two important qualities as no high carbon steel could, and at the same time permits rapid and easy machining. This fact, of economical machining of parts out of soft material, is the real reason for the high importance the process has attained as a manufacturing process during the last quarter of a century.

The temperatures at which the steel is carbonized, and heat treated, have a very marked effect upon the physical qualities of both the case and core; since the operation of carbonizing, under the most favorable of conditions, always leaves the metal in a condition of almost absolute ruin, if no heat treatment were to follow the carbonizing. Fig. 3 shows a fracture of a bar of steel which was subjected to a carbonizing temperature of 1750 degrees Fahr. for a period of 6 hours. It has had no heat treatment but is in the condition in which heat and the carburizer left it. It was cooled in the carbonizing pot and was then broken to show the structure of the metal. This sample is typical of all carbonized steel before receiving heat treatment; it is brittle, and also very soft, and its physical qualities are not as high as a poor grade of gray iron would be. The structure is coarse by crystalline throughout, with no definite division between the core and case; and the whole structure seems to be lacking in cohesion, and suggets to the eye, something that is just ready to fall apart of its own volition. A microscope reveals only a slight difference in the conditions visible to the unaided eye, and shows that the structure of case is a bit closer and somewhat finer grained. The lack of cohesion, however, is more pronounced when observed under the glass.

In order to make this metal of any value, it becomes necessary to subject it to heat treatment. If the highest quality is desired in the structure of the core, the heat treatment must be at such a temperature, and of such a nature as will place it in the condition it was in before the operation of carbonizing disturbed its structure. This means that the metal must be heated slightly beyond its critical temperature and quenched. After this has been done and the highest quality is desired in the case also, the same treatment must be given for the higher carbon case. When these treatments have been given the steel a fracture of the metal will show as in Fig. 5.

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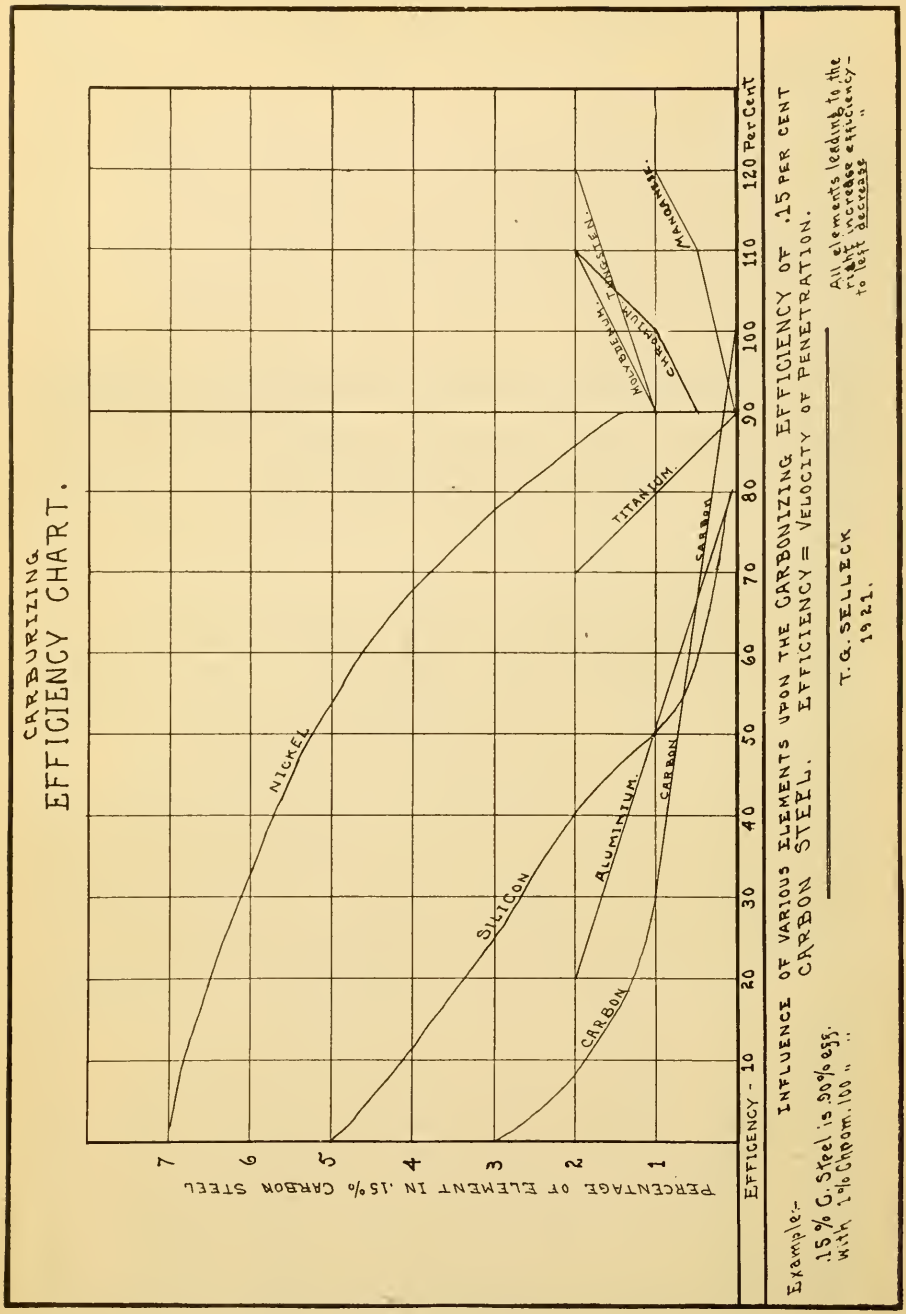

Fig. 2

It is sometimes the practice of casehardeners to quench steel direct from the pot at temperatures very close to the carbonizing temperature. While this sometimes is practiced without any serious results, it is poor

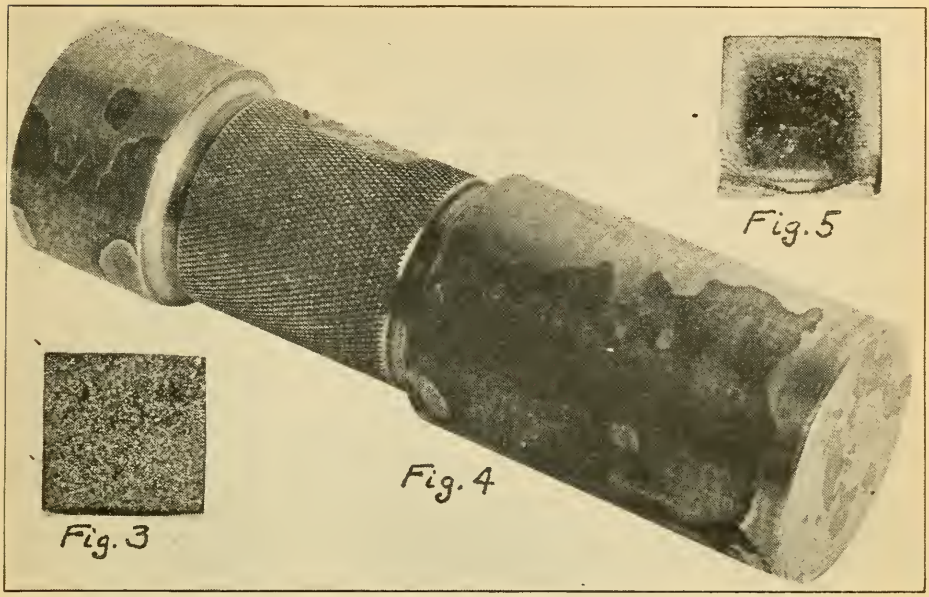

Fig. 3—Fracture of Steel Bar Subjected to a Carbonizing Temperature of 1750 Degrees Fahr. for 6 Hours. Fig. 4—Plug Gage Carbonized at High Temperature and Quenched in Water Directly from Pot. Notice the Spalling. Fig. 5—Same as Fig. 3 Heated Slightly Beyond the Critical Temperature and Quenched

practice, and parts so treated never possess anything approximating the quality they should were they handled properly.

Other casehardeners allow the parts to cool slowly in the pots and reheat for a single quench. In such cases sometimes great economy is effected if the loss of parts through failure to pass final tests does not absorb all the saving of an extra quench.

Quenching from the pot may result in very serious losses, as will be seen in following paragraphs of this article, and the single quench treatment may bring such a variety of troubles that it would take too much space to enumerate them; but if it must be done, the operator should know first, whether the core or the case is most essential to the value of the part; second, he should know approximately at least, the carbon content of both the case and the core; and his treatment should be based upon one or the other for there is no one temperature which can give maximum quality to both. With some manufacturers and their hardening-room assistants, it is often a matter of getting things hard without reference to any special quality that the work must show and in such cases it is of little use to give advice; but to the casehardener who has quality of work in his mind the writer suggests that he always makes sure of every point, especially in the heat treatment of his carbonized parts, for as shown, carbonizing itself absolutely ruins the structure of steel. Thus it is up to the steel treater to redeem it.

The effects of high temperatures, both in carbonizing and in heat-treating, are more marked in the quality of the case than in that of the core, because the core is always the same steel after carbonizing that it was before, and has the same critical point. The case, however, has assumed a different chemical constitution, different physical qualities, and

has become a complex steel, instead of a simple, homogeneous metal that it was in the beginning, and it requires a more exact knowledge of its constitution and physical qualities in order to determine the treatment it should have for its highest refinement.

Carbonized steel has often been referred to as a "double steel", because of the two zones of "low carbon" and "high carbon" set up in the carbonizing of the metal; but it is more complex than a simple double steel. If we consider the conditions, we find in the chemical make-up of the case and the various physical conditions that are established in the application of heat thereto during the carbonizing as well as the heat treating operations.

It will be well for us to consider here something of the manner in which the case is made up, and its true relation to the core. As we have learned, in a previous article on the subject, the carburization of steel is produced by the introduction of carbon into the metal from the surface toward the core; we find that during this introduction of carbon that that element is always more abundant at the extreme surface of the steel than it is at any point between the surface and the uncarbonized core; in other words, there is a gradual lessening of carbon content between surface and core, and no abrupt line of division between them. The percentage of carbon that will be present in the surface of the case depends most largely upon the carbonizing temperature to which the steel was subjected and partly, to the manner and nature of the heat treatment given it subsequent to carbonizing.

The accompanying chart, Fig. 1, shows the relative amount of carbon that steel will absorb when carbonized at various temperatures. It will be noticed that this chart is based upon the researches of David Flather, who in 1903 in a technical journal, stated that: "Iron, saturated with carbon at 700 degrees Cent. can contain only 0.50 per cent carbon; at 900 degrees Cent., 1.5 per cent carbon; at 1100 degrees Cent., 2.50 per cent carbon." These values are given as for the saturation of the iron in the metal; that is, the iron at those temperatures will contain the percentage of carbon indicated. In the application of the carbonizing process there is to be considered the fact that there is always a saturation of the metal on the extreme surface and that saturation is maintained as long as the temperature is maintained. From that saturated portion of the metal the carbon diffuses into the metal just as water will diffuse into wood when the surface of the wood has become saturated with it; or, if it is desired to visualize the process, take a pail of water and with a medicine dropper run a small stream of bluing around the edge of the pail just above the water and notice how the blue saturates the water at the edge and gradually diffuses itself toward the center of the fluid. In like manner does the carbon find its way into steel; and the saturation gives way to gradual diminution of carbon content as it approaches the core.

In the preceding paper the theories of the operation of the process were discussed, and among them the theory of "molecular migration". In connection with that theory there is another old one that fits in well with it and makes the chart in Fig. 1 more easily understood. This is the theory that all carbon is dissolved at the surface of the steel, in all carbonizing operations, and is not deposited from gases entering the metal.

Some of the phenomena observed in the manipulation of the process

seem to point to some such condition existing at the surface of the metal, for if we take a piece of carbonized very low carbon steel from the carbonizing pot while it is at a carbonizing temperature, and quench it quickly enough to avoid any possible chance of the carbon burning out of the metal when it comes into contact with the air; and have the quenching medium a very fast one, such as brine or ice water, we find a concentration of carbon at the extreme surface greater than we ever experience in the cooling of the steel in the carbonizing mixture and reheating, or even in the ordinary quenching direct from the pots. The carbon is there as a solid solution which has not had an opportunity

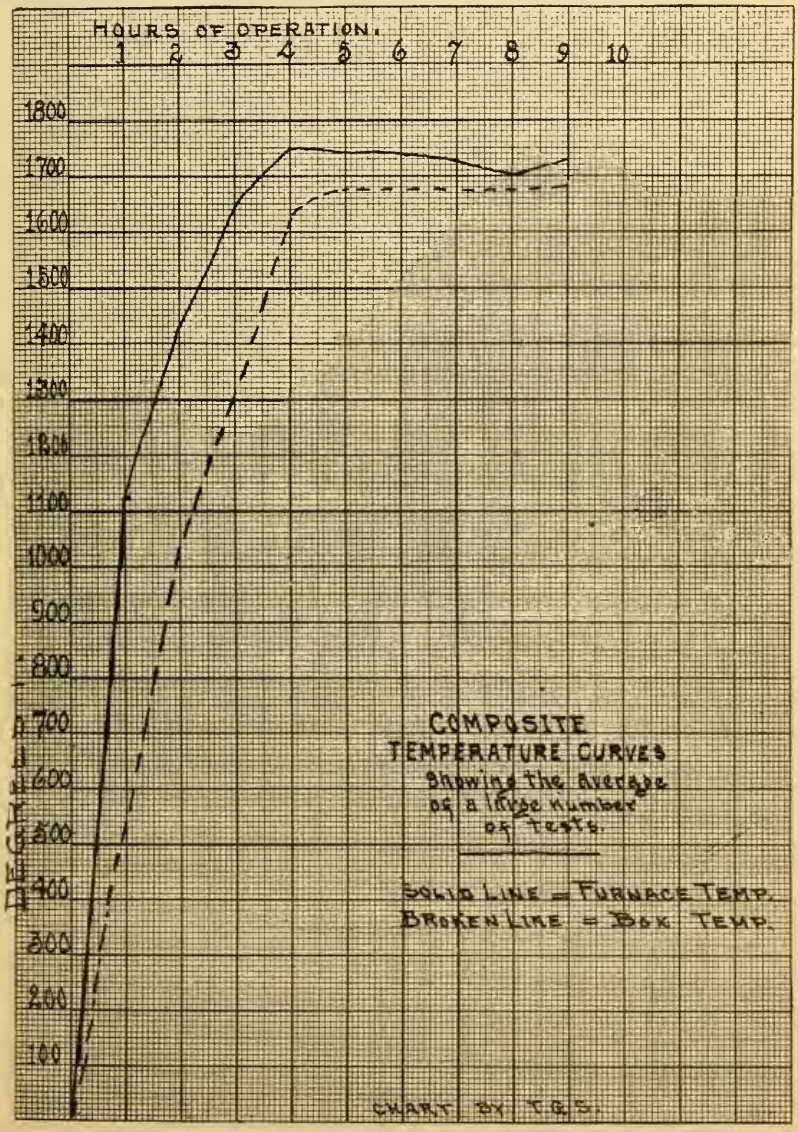

Fig. —Curves Showing Comparative Temperatures Inside and Outside Carbonizing Boxes During Carbonizing Operations

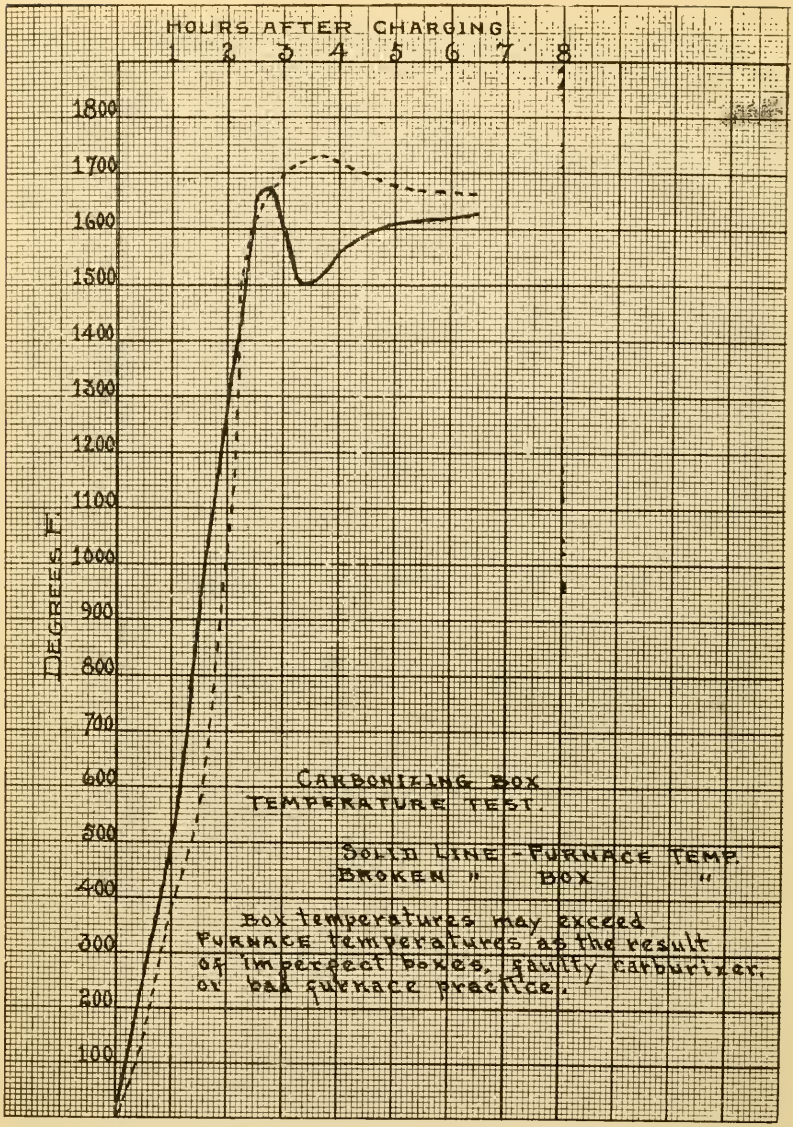

Fig. 7—Curves Showing Excessive Temperature Established Inside Carbonizing Boxes After Furnace Temperature Has Been Lowered

to diffuse into the metal, and it is always there in a percentage equal to the saturation point of the metal.

This saturation and diffusion of carbon is responsible for the great complexity of the case referred to; it establishes in the carbonized portion or case what are recognized as three zones of varying carburization. These are known according to their carbon content as the hypo-eutectoid, eutectoid, and hyper-eutectoid. The first of these zones, hypo-eutectoid, is that containing the lowest percentage of carbon, and lies next to the core; its carbon content is under 0.87 per cent; the next, or eutectoid

zone, is that portion of the case lying next to the hypo-eutectoid, and contains 0.90 to 0.95 per cent carbon; while the hyper-eutectoid contains above 0.95 per cent of carbon. Thus we see that if we carbonize at temperatures above 900 degrees Cent. (1562 degrees Fahr.) we are quite sure to have a hyper-eutectoid case, and if we keep below that temperature we may have a case of most any desired carbon content.

In practice we would have difficulty in establishing an exact schedule of temperatures for the various requirements in carbon content of our work, but we may be assured that if we carbonize at a certain temperature we will have in our case, for a certain depth at least, the amount of carbon the chart indicates. Such depth is sometimes so slight as to make it difficult to get a chemical analysis, but photomicrographs often prove such values in quite a convincing manner.

After steel has been carbonized the heat treatment of it must be governed by the nature of the service that the steel will be obliged to render. If a hyper-eutectoid case has been established and the requirement is for extreme hardness without the need of any particular toughness in the sharp edges or the lighter sections of the material, the quench for the case should be at the critical temperature of approximately 1.00 per cent carbon steel, without any subsequent draw; but if the wear to which the parts are to be subjected is abrasive in character such as gears, or dies, the parts should be given a draw of approximately 400 degrees Fahr.; the exact temperature of the draw can only be determined when the scleroscope or Brinell hardness requirement is known. It is a matter usually for the operator himself to determine by test, since there are always variations in steel, and in conditions within the shop that make it impossible to establish exact rules for hardening steel that may be followed successfully by all steel treaters.

In submitting these considerations on the subject of the relation of temperature to the quality of case and core, there is still another matter of vital importance touching upon this question. That is the effect which certain elements have upon the carburization of the metal when such elements are introduced as alloys.

Fig. 2 is a chart showing the carbonizing efficiency of steels containing certain percentages of such elements as are usually alloyed with low carbon steel. The carbonizing efficiency is based upon the velocity of penetration that it is possible to obtain in the alloyed steels when compared with plain carbon steel. It will be noticed that the curves leading to the right, from the meridian line are the elements which aid the absorption of carbon by the steel, and so increase its efficiency, while those leading to the left are the elements that retard penetration, and lessen the carbonizing efficiency of the metal. In endeavoring to balance these different effects we find it necessary to increase the carbonizing temperatures for those elements which retard carburization, and lower it for those that accelerate carburization. In heat treatment after carburization we find that we must pursue the same course, giving milder treatment to the alloys that add efficiency, and higher temperatures, and more severe quenching to those that lower the efficiency of the metal in carburizing. For instance, a high nickel steel will stand a much higher temperature for the normalizing of the core than a high chromium steel will and a harsher quench.

There is, however, one exception to this rule that must be mentioned here most emphatically, and that is in the case of carbon where

the carbon content runs above that of mild steel, the metal should receive the same treatment given the higher alloys, such as chromium, manganese, etc.

A single quench for carbonized parts always should be avoided where it is economically possible, and should never be chanced where the carbonizing temperature exceeds 1650 degrees Fahr. if quenching from the pot is necessary for such practice results so often in the absolute loss of parts so treated, that the chance of avoiding trouble is really so small that it is not worth considering. Fig. 4 shows a photograph of one of a

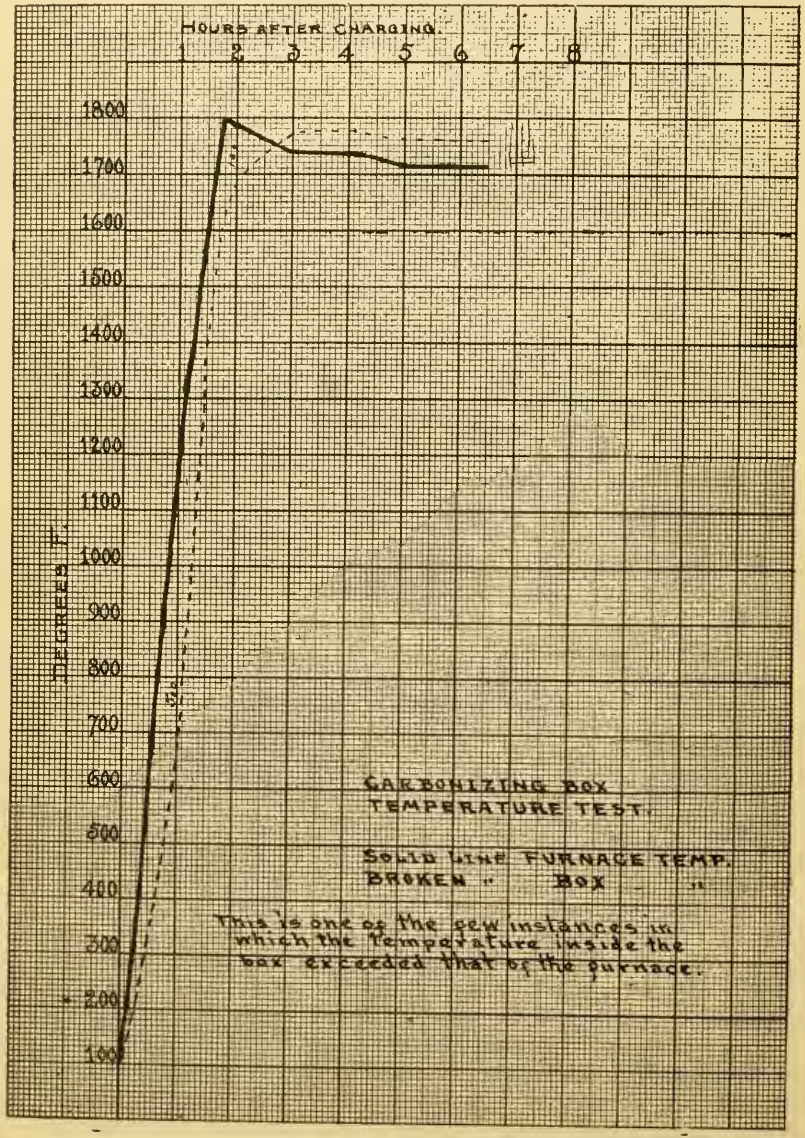

Fig. 8—Curves Showing Temperatures Inside and Outside Carburizing Box, the Box Being Imperfect

number of plug gages carbonized at a high temperature, supposed to be around 1650 degrees Fahr. but apparently very much above that range, and quenched from the pot. These gages were reduced perceptibly in their diameters by the spalling off of a case of very high carbon from their entire surfaces. The explanation of the trouble is quite clear, and is found in the explanation given in the preceding paragraphs of the chart in Fig. 1. Carbonized at very high temperature, (the degree in doubt), the gages were taken from the carburizer while at their carbonizing temperature and quickly quenched in water. The saturated surface of the metal had no chance to yield any of its surplus of carbon by diffusion to the layers of metal laying next to it, or unite by any welding process to the less carbonized portion, and in the severe quench it became a loose cylinder of metal of a character that possessed no strength or homogeneity, with the result that it just fell away. This is an excellent example of "enfoliation", a fault that is common to the practice of single quenching from the pot.

If these parts had been allowed to cool down slowly in the carbonizing material, and had then been given a quench at the proper temperature, probably they would have been saved. However, it is not always that direct quenching is responsible for spalling or enfoliation, and high carbon content and excessive concentration of carbon at the surface of the metal are not always accompaniments of this sort of failure. We often see the same condition on steel parts that are ground after hardening, when the fault can be traced directly to faulty grinding; then again it may occur in carbonized parts made from nickel steel with a carbon content above 3.00 or 3.50 per cent, even when the parts have been cooled slowly in the pots, due to high concentration of carbon in the surface of the metal, in which case treatment recommended by some steel treaters is to heat the metal slowly for the heat treatment of the parts after carburizing; or in the carbonizing period, to add to the carbonizing time sufficient to allow a gradually diminishing temperature. That is, if the carbonizing temperature is 1750 degrees Fahr., and the carbonizing time is 8 hours, 2 hours additional should be added to the time to allow for gradually reducing the temperature to 1650 degrees Fahr. The reduction should be gradual to permit the carbon to diffuse through, or into the inner layers of the metal, thus avoiding the high concentration of carbon at the surface.

Surface cracks, showing on polished pieces of carbonized steel, may be traced also to the use of improper carburizers, or the improper use of good carburizers. The photo shown here was carburized with a nationally known commercial carburizer, and one that has been used for a long time by the company in whose plant this failure occurred, and by a casehardener whose service with the company has been highly satisfactory. Undoubtedly in this case one of those very rare conditions of excessive internal combustion was the underlying cause of the failure; while among a certain class of casehardeners the theory of a higher temperature inside of carbonizing boxes than outside is pretty well fixed. Tests very carefully made have proven that, while such a condition may occur, it is very rarely established, unless a very faulty carburizer is used, or the pot or box is in bad condition and permits the ingress of oxygen, or pots are used without covers and violent combustion proceeds from the exposure of the carburizer to the furnace gases. If a carburizer containing inorganic carbon with hydrocarbons is used, such combustion may

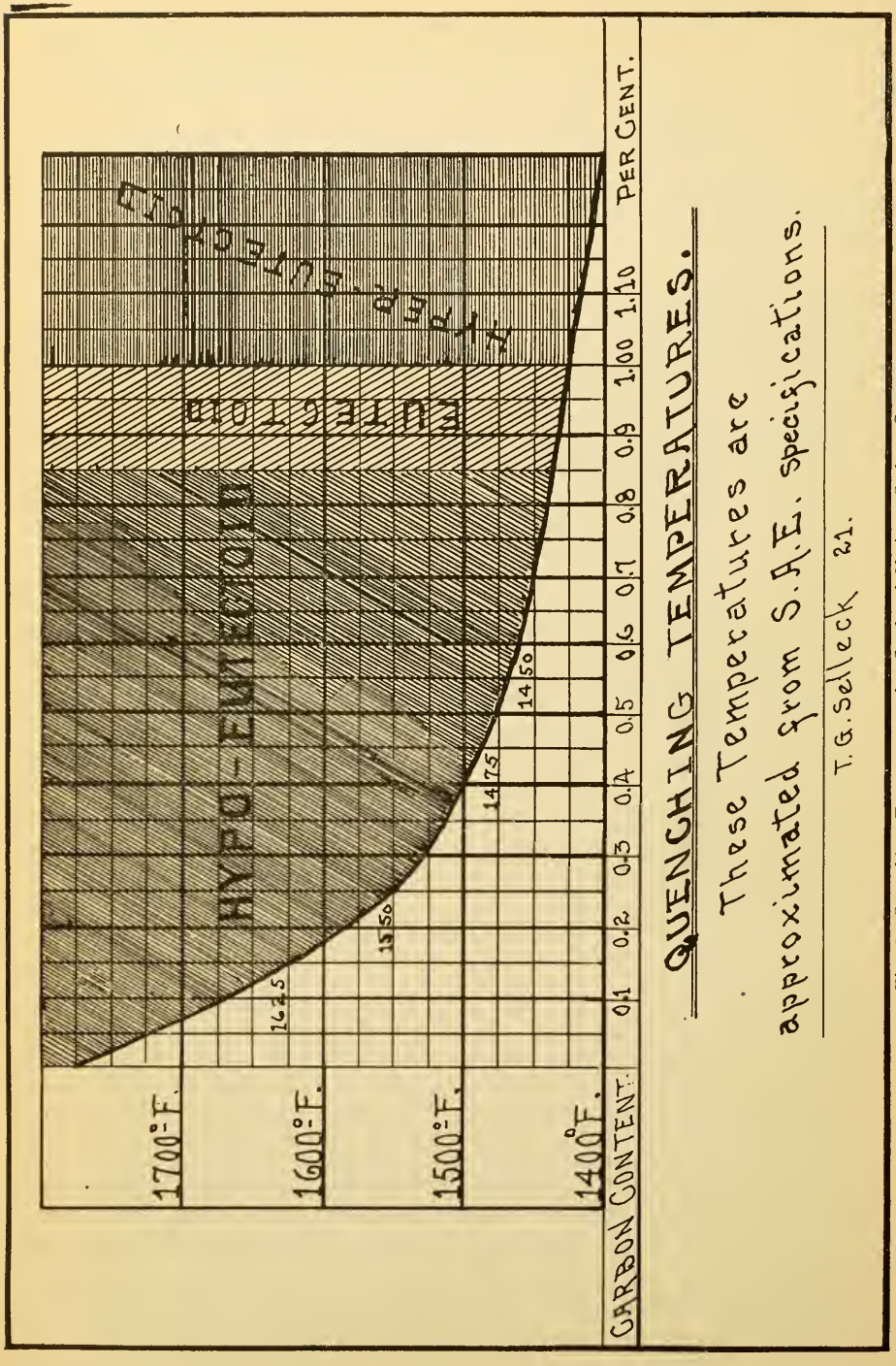

Fig. 9—Quenching Temperatures for Steels of Various Carbon Contents

take place without any of the other conditions being present; if bone is used, as the writer has frequently seen it, in pots without covers, excessive temperature may be established in the pot. Just why a casehardener will use a pyrometer in his work under such conditions, the writer can not understand; he says that his temperature within the pots is higher than outside or greater than his pyrometer indicates, "anywhere from 100 to 200 degrees Fahr.", he does not know just how much. A pyrometer is an investment under such circumstances that will never pay interest; and yet they are the ones who usually spend the most time watching the pointer, have the most trouble and more frequently write to somebody a 1000 miles away to tell them what to do to overcome their failures. A chart is shown in Fig. 6 giving the comparative temperatures inside and outside of carbonizing boxes during carbonizing operations; these are composite curves made from a long series of tests. This chart shows that under regular conditions the inside of carbonizing boxes is at a much lower temperature than that of the furnace.

There are conditions, as stated, when an excessive temperature is established inside of carbonizing boxes, and will even increase there after the temperature of the furnace has been lowered. One such test is shown in Fig. 7. In this case it will be noticed that the temperature inside of the box was higher than that of the furnace chamber for a period of more than 3½ hours, and while the furnace temperature was falling rapidly, the box temperature was rising almost as rapidly. The cause of this condition was a very combustible carburizer made chiefly from coal products containing oil and other hydrocarbons, which produced gas at very low temperatures and at such velocity that the sealing of the box was of no use. Fig. 8 shows the result of another test of the same character, in which the trouble was not caused by the carburizer but by an imperfect box. In this case a small blow hole in the cast-iron box permitted the entrance of enough oxygen to stimulate the combustion of the organic matter of which the carburizer was composed. However, in the composite curve shown all of these various conditions are represented in the average indicated.

The writer does not wish it to be understood that he considers this composite curve a fair average of the conditions obtaining in general practice of the carbonizing process, for these tests were made under conditions which perhaps would not be considered the average, and he believes that under the best modern shop conditions a better result than this would be shown by similar tests. The author does believe that in the average casehardening plant the operator is very much off in his estimate of the time required to bring carbonizing boxes to the temperature of the furnace, as indicated by his pyrometer, especially when little care is shown in the proper placing of the thermocouple. If some operators would take the pains to check up on themselves, they would meet some surprises. In these charts it will be noticed that the variation of temperature between the inside and outside of the boxes was very pronounced, sometimes for several hours, and the composite curve shows that as an average, there was a difference between the two temperatures of about 125 degrees after 4 hours of heat.

The boxes used in these tests were of standard size, of the following inside measurements: 4 inches wide, 6 inches deep and 18 inches long. Various carburizers were used to determine the comparative heat conduc-

tivity of various compounds, more about which we will consider in later articles.

The relation of temperature to the quality of case and core is a very direct one, as indicated by the straight carbon line shown in the chart in Fig. 1. This is for the carbon content of the case and should indicate to the operator the heat treatment of the case. In Fig. 9 is shown the quenching temperatures of steels of various carbon content, which will be useful to the operator who desires knowledge of the proper temperature for the refinement of the core or case. This chart does not take into consideration the presence of any alloying elements in the metal.

There are no hard and fast rules for the treatment of carbonized steel, beyond that of the strict observance of the critical temperatures of the metal. This is at times difficult to determine without scientific apparatus for the purpose, and the average casehardener can not avail himself of the use of those important and expensive instruments; so it becomes necessary for him to use his common-sense, and proceed slowly in all his operations until he knows he is right. Where a critical point is in question, and no equipment for determining it is at hand, practical tests should be made until the fracture of the metal indicates the proper temperature is established. It is always better to sacrifice a few parts for the establishing of proper heat treatment than it is to go ahead blindly and perhaps sacrifice thousands of them later with the added sacrifice of a customer's business and good-will.

STANDARDIZING SPECIFICATIONS FOR TOOL STEEL

By Charles M. Brown*

(A Paper Presented Before the Pittsburgh Chapter)

A curious and remarkable state of affairs exists in the tool steel trade. For a number of years efforts have been made by individual consumers and by technical societies to write standard specifications for carbon tool steel with practically no effect on the manufacture of tool steel and without any marked influence on general buying, while at the same time high speed steel has become practically standardized without effort on the part of any individual or society to draw up a specification.

This has been brought about on the one hand by the failure to take into consideration to any great extent the really decisive factor, namely, cutting ability, whereas this same factor has been responsible for reducing high speed steel to a standard article.

The first attempt to draw a specification for tool steel of any kind, so far as we know, was made some 15 or 16 years ago by the General Electric Co., Schenectady, N. Y. This effort undertook to divide carbon tool steel into three distinct grades or qualities to be determined by the chemical analysis, with the additional provision that the steel must be made by the crucible process and must be free from the common mechanical defects such as pipes, seams, etc. This example since has been followed by a number of manufacturing companies and by several railroads, and while these efforts constitute a step towards standardizing for the particular shops for which the specifications were drawn, there are so many differences in the analyses and stipulations such that if the practice grows

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the result will be the opposite of standardizing. A greater tendency than ever will result towards specializing in the manufacture of tool steel for particular users—a thing which on every account should be avoided. Prompted by the example of these individual consumers, several of the technical societies, notably the American Society for Testing Materials, have attempted to write a specification for tool steel which would be standard for general use.

Almost without exception these attempts at writing specifications have been opposed steadfastly by the toolmakers. Several reasons for this are evident. To begin with, the fear exists for the effect they would have on the prestige of long established brand names. Proper recognition should be given to those steel makers who by years of careful study and determination have produced efficient and dependable brands, but this need not enter into the discussion of the practicability of standardizing. The steelmakers, however, have found practical objections of two kinds, both more or less justified and founded on good reasons. The first objection is that none of these specifications have provided any way for determining the real essential in tool steel, that is, its cutting quality.

When the steelmaker has had placed before him specifications prepared by some user, the natural question was "Why do you want steel of this kind?" The natural answer is this: Because we have been using entirely too many kinds of steel and we believe that a steel made to this specification will simplify our work and give better results." To this the steelmaker replies, "The specification as you have have drawn it does not aggree with any steel that we regularly make, but if you insist upon obtaining steel to your specification we will be glad to make it, in which case no doubt you will assume all responsibility for its doing the work." This is not unreasonable if the specification is what it claims to be, a method of providing good steel. This obstacle has been overcome in the specifications of the United States Navy Department by providing for actual shop working tests, and by making awards on the basis of these tests rather than by strict fulfillment of their chemical provisions. In almost all other cases the steelmaker's final reply has been: "If you expect me to continue to guarantee that the steel will do good work, you will be wiser if you leave all the details of the composition or manufacture to me."

The second objection relates to details. The carbon content in any individual specification seldom agrees with the standard practice of the steelmaker. In any process of melting more or less off-carbon heats, will result, especially in the crucible process where the practice of casting every pot separately into one ingot is followed, with the result that as many different kinds of steel and as many different percentages of carbon as there are pots in the furnace will result. The extremes in these carbon ranges, in some cases will be wide, and even where the ladle process is used and the contents of all the pots in the furnace are emptied together and cast into two or three ingots, still some chances of variation in the carbon content exist. Charcoal, which is used for adding the carbon, is very volatile and some portion of the charge will escape. The crucibles used are about 55 per cent pure carbon, some of which is lost during the melting and enters into the steel, a larger amount in new crucibles than in old ones, and these factors sometimes result in a greater or larger amount of carbon than ordinarily expected. The standard practice allows for 10

points range, thus heats which come outside of the standard range are considered off-heats and unless a market be found for these, they must be remelted. This increases the cost of manufacture.

It must be remembered also that carbon tool steel is used for a great variety of purposes under widely different conditions. Some operations require a very hard steel and others just the reverse, toughness having more importance than hardness. The steelmaker cannot know, in the majority of cases, for what purpose the steel will be used, and consequently must regulate the carbon content according to that experience which has proved to be the most common tools made of specified sizes and shapes. For example, round bars commonly are used for taps, cutters and similar tools, and might contain from 1.10 to 1.20 per cent carbon; flat bars mostly go into die work for shearing and pressing metal for which 1.00 per cent carbon gives good results; chisels made from octagons should be about 0.80 or 0.90 per cent carbon; and square bars used for hammers, sledges and similar tools about 0.75 or 0.80 per cent carbon. By arranging a schedule of this nature a point is found for steel of any carbon content between the highest and lowest extremes. Usually, if a buyer comes with his own specification stipulating one range of carbon and suitable for his own particular shop conditions, he is almost invariably asking for steel which is not the maker's regular standard and which requires him to undertake a special manufacturing operation. These statements are made in explanation of the opposition which has prevailed on the part of the steelmakers at attempts to standardize up to this time, and to explain the lack of progress.

Before going further it is best to give a definition for the term "tool steel," a term which often is indefinite. As we shall use it, tool steel is any steel for cutting tools or implements which are hardened and tempered.

Studying the field thus outlined, we will find that standardization has already taken place to a marked extent. Wherever figures of proved performance can be determined accurately and the decision is based on the cutting service of the steel, the result has been a rather common agreement between buyers and makers upon a standard form of composition. Word passed from the manager of one factory to another and from them to salesmen and back to the makers has brought a pretty general agreement on certain types of steel as best fitted for certain uses. A number of standard types are already familiar to us.

High speed steel practically is standardized in two types. The first of these and the one most generally in use is known as 18 per cent tungsten-vanadium steel and will be found to conform to the following composition:

	Per Cent
Carbon	0.55—0.75
Manganese	0.20—0.40
Silicon	0.10—0.30
Chromium	3.00—4.00
Tungsten	16.00—18.00
Vanadium	0.50—1.00

Probably from eight to a dozen different makes of steel now are on the market conforming to this standard composition.

The second type of tool steel is lower in tungsten and higher in vanadium, conforming to the following composition:

	Per Cent
Carbon	0.55—0.75
Manganese	0.20—0.40
Silicon	0.10—0.30
Chromium	3.00—4.00
Tungsten	12.00—14.00
Vanadium	1.50—2.00

This second type, although not so commonly known nor having as many supporters, nevertheless is to be obtained in several brands and is considered suitable for some purposes. A standard type of finishing steel is known by this name, and is procurable from a number of different manufacturers. It contains tungsten from 3.5 to 5.0 per cent and carbon sufficiently high to enable the tool to hold a keen cutting edge. Twist drill manufacturers use for their carbon drills a standard steel containing carbon about 1.10 to 1.25 per cent and about 0.50 per cent chromium.

Oil hardening steel is a standard type and can be obtained from a number of different manufacturers. It has the following composition, based on results proven by the original promoters on this type of steel:

	Per Cent
Carbon	0.80—1.00
Manganese	1.25—1.75
Silicon	0.25—0.40

This type might be classified in another way as a manganese alloy tool steel. It is true that oil hardening steels of different composition are made and offered on the market, but their success in no way approaches that of the standard type generally used.

For hot heading work on bolts and rivets, two standard types are available, one corresponding to a low grade high speed steel containing 11 to 13 per cent tungsten but with a lower carbon content than would be suitable for high speed steel cutting tools. In place of this, a number of manufacturers are offering and producing good results with steel containing 0.75 to 0.85 per cent carbon and about 3.5 to 4.5 per cent chromium.

For rivet driving sets there was at least during the war some approach towards standardization as the Emergency Fleet Corp., the largest consumer of steel for this purpose, put out a specification calling for steel to contain a definite amount of carbon, manganese and vanadium.

It will be noted that no reference has been made in the above to the question of phosphorus and sulphur, in spite of the fact that books would be required to record all the controversies which have been waged as to how much sulphur and phosphorus was permissable. Judgment as to the permissable limits of phosphorus and sulphur has changed considerably during recent years, it now being conceded that larger amounts of phosphorus and sulphur safely can be permitted than was formerly believed. As a matter of fact, in some cases, it is possible to get phosphorus too low as certain tools which require great surface hardness are helped by a slight inclusion of phosphorus beyond what was once thought desirable for the very finest steel. It is also noticeable that all of the standard types outlined are alloy steels containing one or more alloys upon which they depend for certain marked and valuable characteristics. This then reduces the obscurity and need for further consideration

to the problem of plain carbon tool steel, although in one way it would seem as if the need was less urgent.

Taking a period about 25 years ago before the possibilities or qualities of high speed steel were discovered, practically speaking, all tools were made from plain carbon steel with the exception of a very small amount of what was then known as self-hardening steel, the forerunner of high speed steel. Consequently, carbon steels were called upon to perform a wide variety of uses from shearing hot billets or heading rivits to drilling stone, cutting wood, paper, leather and so on to metal cutting tools such as drills, taps and dies. For some of these purposes the steel had to be extremely hard. For others, hardness was not nearly so important as toughness. It is quite natural then that to meet all of these various purposes there were developed and put into use a great many kinds and varieties of carbon tool steels, but today the use of high speed and other alloy tool steels has restricted and made the uses of carbon steels more simple. When any difficult metal cutting job is to be done we use high speed steel. For most of the other operations where carbon steel most often proved unsatisfactory, one or other of the alloy steels above referred to have been adopted. Comparatively speaking, it is for the easy jobs that carbon tool steel is used today. It would seem, therefore, as if the selection of carbon tool steel would be much simpler than ever before.

The question as to the advantages of having definite standards for tool steel from the point of view of the user hardly can be denied. Modern methods, gas or oil-fired furnaces, the use of pyrometers giving accurate records, etc., have made it necessary to use steels of similar and known characteristics. It must not be supposed that the introduction and use of high speed steel and other alloy tool steels have made the use of carbon tool steel unimportant. Such is not the case. No accurate statistics of any kind are available to show how much tool steel is either made or used because up to this time there has never been any agreement as to exactly what shall be included under the term "tool steel" in many shops it is customary to use the term "tool steel" to mean plain carbon tool steel and not high speed steel.

When we define tool steel as any steel made for cutting tools or implements which are to be hardened we cover a great many applications which never would enter into most peoples' minds. For instance, not only steel for mining drills, but also for tillage implements, molds and shares on plows, for cutting knives on mowing and reaping machines, axes, sledges, screw drivers and many other tools, the enumeration of which would take too much time. Twenty years ago all of these steels were made by the crucible process. The growth and tonnage became so large that it was impossible to take care of the business satisfactorily in such small units and the open-hearth process is now relied upon to produce a part of the tool steels of this kind.

Twenty years ago tool steel was synonymous with crucible steel and all the soft center plow steel, all the mowing machine knives, all mining drills steel and all die blocks, were made by the crucible process, where today all of these steels are made by the open-hearth or electric process, as well as a large quantity of the steel used for shear blades, punches and some other tools. They are, nevertheless, just as truly tool steels as ever before, requiring the same great care and careful

manipulation in working and undergoing the same practices in all processes outside of the melting. Omitting, however, the agricultural implement tool steels and mining drill steels from calculation, probably it is safe to assume that there is four to six times as much tonnage of simple carbon tool steel produced as there is of high speed steel, so that its economic place in industry is still of great importance.

In approaching the problem of ideal standards, how much should be taken into consideration? Should it rest alone on chemical composition or include restrictions on process of melting, of materials to be used, or other steps in the manufacture? Analysis not only is useful but essential with respect to steels which contain one or more alloys, and which depend upon these alloys to give the characteristics essential to maximum service, but in plain carbon steel analysis is of little importance to the user. Analysis enables the manufacturer to produce a more uniform product, and where the ladle process of casting is used and a few ingots are produced, it is possible to make a complete chemical analysis of every heat and thus prevent or check any irregularities which might otherwise creep in. But to the user of plain carbon steel, analysis tells little if anything, except the amount of carbon contained and even that is not of great importance. For steel in some applications, it is desirable to have a close range of carbon, but in many cases a wide range can be used without affecting either the heat treatment or the performance of the tool itself.

The amount of phosphorus and sulphur which are permissable depend a good deal on the kind of base material used. Steel made from the best puddled iron can carry safely a higher percentage of sulphur and phosphorus than one made from a scrap mixture such as open-hearth plate punchings or shearings. Chemical analysis will not disclose careless manufacture. It will not disclose mistakes or omissions, improper melting, overheating in rolling or annealing cannot be disclosed by chemical analysis. Proper performance of these steps is absolutely essential to produce tool steel of the proper quality for any use.

Should the specifications call for any particular process of melting? The crucible process of melting is the oldest known method and remains the best, because of the means which it affords for careful handling and watching, due to the small units employed and the 100-pound charge in each pot. But as has been already pointed out, where consumption in any line of tools grows to a large tonnage the crucible process usually has given way to a more economical one. And undoubtedly it will continue to be so, although a place for crucible melting in finest qualities of steel will exist for a long time to come. The electric melting process has been recommended strongly as producing steel of equally good quality, but is definite place in the industry is not yet settled. The open-hearth process, as has been pointed out, is used largely. A process is but a process after all, and is not more fool proof than heat treating, thus poor steel can be made by any method.

As to the question of specifying materials, this is open to like objection. Manufacturers of tool steel honestly differ widely in belief as to what materials produce steel of satisfactory performance, and since as has been found out, so much depends on the skill and care in all the steps of manufacture, it will be impossible to predict that the use of any specific raw material would necessarily of itself result in first class steel.

In any effort to establish national specifications, the co-operation of the steel manufacturer should be sought and obtained, for without it the proposition becomes more difficult. We are of the opinion that the manufacturer should be allowed as much freedom as possible in the choice of processes or of materials, in view of all the widely different beliefs and practices now being used.

Place the most importance on the service which the steel gives. The question is how to provide tests which will determine this service. Cutting ability of course, is the first feature. For some time manufacturers of testing machines, have been working with the hope of developing a machine which would test speciments of steel for cutting ability accurately and rapidly, but unfortunately up to this time no machine has been developed which is entirely satisfactory. It is to be hoped that success in this line will not be long deferred. Until such time it will be necessary to depend to a large extent on actual performance tests made in the shop. It has been found possible in other steels such as structural steels and alloy steel for automobile use to determine the value by physical tests showing the tensile strength, elasticity and reduction of area.

On the other hand, very little investigation has been made to determine what physical tests might be made to show the value of tool steels. For example, for tools such as twist drills or taps, might not torsion tests be valuable and indicative of the quality of the steel? In another way, compression tests would be valuable, the greatest difficulty in this instance being that many steels when hardened and tempered have such strength that it is practically impossible to break them on any of the machines now in use.

Up to the present time, therefore, it would seem that practical possibilities for standardizing types of tool steel exist in defining certain definite types or grades of steel, as follows:

1. High speed steel.
2. A tungsten alloy finishing steel.
3. A manganese alloy oil hardening steel.
4. A chromium alloy tool steel.
5. A vanadium alloy tool steel.
6. A molybdenum alloy tool steel.
7. Steels containing two or more alloys such as chrome-vanadium or chromium-tungsten.

This list might be extended from time to time as new types or varieties are found successful.

This leaves at the bottom the last, carbon tool steel, as a general proposition and it seems wise to leave it at that. In other words, not to attempt to write specification which will distinguish between different qualities or grades of carbon tool steel until more exact means of measuring quality are found, but to provide for one general type or class. It is true and must not be overlooked that there will be wide differences in quality in carbon steels and these differences will continue to result from the experience, skill and care of the manufacturers, for which it appears that no possible method of distinguishing can be found unless or until some simple, cheap and expeditious way of testing cutting value is devised or by some method found for making use of the test of physical properties.

RELATIONS BETWEEN THE PHYSICAL PROPERTIES OF STEELS AND THEIR ENDURANCE OF SERVICE STRESSES

By James E. Howard*

(A Paper Presented Before the Lehigh Valley Chapter)

Shreve in the preface to his translation of some of the results of Spangenburg, published by Van Nostrand in the year 1876, made these remarks:

"The results of these very important experiments have been before the profession for some years, but, strange to say, seem to have attracted no attention; and tests of iron and steel still go on for the purpose of determining their elasticity, their elongation under strain, their ultimate strength and other qualities, while Wohler and Spangenburg's experiments show that it is very doubtful that these bear any proportion to the durability of the metals".

These remarks of Shreve, made 45 years ago, are well to keep in mind since they describe a condition which has continued in a degree down to the present time. Efforts are made currently to impart high physical properties to steels in their primitive state, the relations of which to the endurance of service stresses are in a measure conjectural. It is believed generally that the possession of these high primitive properties improves the steel for useful purposes. If such opinions did not prevail there would be no justification in demanding those high properties in the specifications governing the acceptance of the metal. Going a step further, the query may be made whether the imparting of these special properties is in all cases beneficial, whether negative results may not be encountered, if perchance the treatment happens to be injudicious.

Existence of the American Society for Steel Treating carries with it the inference that steel in its natural, annealed state is not in its best condition to meet all of the requirements of the arts. Those properties which inherently pertain to steel in a well worked and annealed state inadequately meet the needs of service. A combination of physical properties distinctively modified over those which naturally attach to the steel as governed by its chemical composition, increases the permanent value of the steel, basing the deductions upon the results of the testing machine with a single application of load increased to the limit of rupture.

It would seem properly one of the functions of this society to advance information along certain lines and firmly establish relations which are now obscure. A distinction is made between the working of steel and the treating of steel. As steel treaters you are expected to regulate the properties of the steel after it has been properly shaped by the operations of forging, or rolling, or perhaps after machining, and bring the steel into a state of greater efficiency.

The mere fulfilling of the requirements of a given set of specifications does not present itself as the vital feature unless it is shown that the specifications themselves are right. The framing of specifications depends upon antecedent knowledge of the behavior of the steel under those conditions which it will be subjected to in service. Such information is not as accessible to the steel treater, as a rule, as it is to the steel user. The use of steel, therefore, furnishes one of the best illustra-

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tions of the need of cordial, reciprocal relations between the steelmakers or steel treaters and the steel users.

Steel is most commonly used for resisting loads or stresses which may be those of tension, compression or shear. The stresses may be constant, intermittent or in alternate directions. In the abstract, the problem of the steelmaker or steel treater is to furnish a steel which will endure the widest range of loads or stresses without loss of integrity. In approaching the subject in this manner it is preferable to speak of strains instead of stresses. Strains represent the deformations which attend the application of stresses. In a way, it is immaterial how the loads or stresses are provided, the deformations of the steel are kept within limits.

In judging the endurance of steels to service conditions it is simpler to think of strains than stresses, although under most conditions of loading a definite ratio exists between the two, as expressed in the value of the modulus of elasticity. A strain of one thousandth, not 0.001-inch but one thousandth of the length of the member under consideration, represents a stress or load of 30,000 pounds per square inch, according to the value of the modulus of elasticity taken at 30,000,000 pounds per square inch.

It is obvious that when steel is ruptured, certain adjacent particles are separated beyond their range of activity; the bond connecting them has been severed. The difference between a low carbon and a high carbon steel in respect to their elastic limits is that one has a greater elastic range than the other. This elastic range under some circumstances is a measure of the stress which the steel is capable of enduring although this statement must be made guardedly and subject to limitations and qualifications. If this were not done, the elastic limit of the steel in the direction of loading would be an index of its durability and ability to endure service stresses.

It is desired to emphasize this manner of regarding steel according to strains rather than according to stresses. It is the deformation or movement of the metal within itself in respect to the relations of adjacent particles to each other which constitutes the vital feature; the strain which the steel endures. A strain is produced by the application of a load or stress. One is the cause the other the effect. It is the effect with which we are concerned. A condition of loading may exist when adjacent particles are not separated and under such a condition it is probably safe to say rupture cannot be accomplished however great the stress may be. Such a case is presented in the cubic compression of steel, that is, when compression stresses are simultaneously applied in three directions. Modified conditions are presented in impinging pressures between a sphere of large radius and the plane surface of a block of steel of large cubical dimensions. The maximum intensity of the pressure in this example may be very great but the graduation of pressure from the maximum at the center of the impinging area to its periphery may be such that no two adjacent particles are separated beyond their normal range of activity, or beyond the radius of molecular action as it is called. A common example of this action is found in wheel pressures on the heads of steel rails. Unconsciously this feature is considered in railway engineering, in the use of wheel loads which from a metallurgical point of view are excessive.

Providing steel is not strained beyond a given amount, no reason exists for doubting its indefinite endurance. It is necessary, however, in

this connection to take into consideration not only the strains which result from external loads but also the state of internal strain of the steel. This second factor is one which has been overlooked generally, in engineering structures, little consideration has been given the influence of internal strains in the metal. These strains are just as tangible as those which result from external loads and it is believed they account for cases of rupture which are not adequately explained by reason of the magnitude of the external loads. There are examples in which internal strains appear to exceed those resulting from external sources, the overlooking of which therefore neglects the principal factor in the cause of failure of the steel.

It is held to be a matter of deep concern as to how and when these internal strains are introduced and their magnitude. They may result from cooling strains during fabrication of the steel, that is by thermal means, or they may be the result of mechanical work in the cold state, such as cold rolling or cold drawing. The general effect of such treatment whether thermal or mechanical, is to increase the rigidity of the steel against permanent deformation, or modify its rate of deformation under stresses which exceed its elastic limit and approach rupture.

Necessarily internal strains can only exist in couples. An internal strain of compression must be balanced by an internal strain of tension. Variations in magnitude may exist, since a larger volume of metal in a state of tension may balance a smaller one in compression. Graduations in strains of the same kind in different parts of the section also occur. Measured strains show the mean values in the detached strips on which the observations are made, hence such values are below the maximum.

Measured strains necessarily represent those which prevail in a considerable volume of metal. They are obtained by establishing gaged lengths on different parts of the periphery of the steel member after which strips are detached by machine tools. The expansion or contraction of the strips show whether that part of the steel member was in an initial state by compression or of tension respectively. The resilience of the steel, that is the strain displayed by the detached strips, show the magnitude of the internal strains. Internal strains expressed in their corresponding stresses amount to many thousand pounds per square inch.

These bulk values are conservative values and commonly fall below the values which are reasonably certain to have existed. A change in the density of the steel seems to account best for the presence of internal strains, in respect to mass formation. There are reasons for believing that intermolecular strains exist, the aggregations of which are represented by the bulk values. It is but a step further to infer that internal strains may attain such a degree of magnitude that spontaneous rupture of the steel may occur, and when such an example of rupture occurs, there will be no display whatsoever of ductility in the steel, notwithstanding its ability to display normal elongation and contraction of area in the tensile test.

It is well known that spontaneous rupture does take place in hardened steel, not only at the time of quenching but later thereby releasing some of the internal strains. When internal strains exist, and since they must be in couples, it follows that the elastic limits first will be reached locally; in one part of the steel, if loaded in tension, in another part, if loaded in compression, since the internal strains

and those resulting from the external load of the same kind must be added together to show the total strain in any one part.

Heat treatment in respect to the quenching of the steel must perforce introduce internal strains. Subsequent drawing of the steel relieves some of them, substantially all, if the drawing becomes an annealing operation. The modified physical properties remain in evidence and in degree according to the states at which these operations are suspended. There is nothing mysterious or occult about these modifications in physical properties, although experience is required to attain certain pre-determined results, in the primitive tests of the steel. But as Shreve remarked 45 years ago there is nothing in these primitive tests, in themselves, to indicate what permanent advantage has accrued from effecting these changes in properties in respect to the steel enduring service stresses which do not resemble the methods or manners of a tensile test. The purport of these remarks is to call attention to what must constitute proof of the advantages of employing different methods of treatment.

A great wave is passing over the steel industry in the effort to secure steels of superior efficiency. Alloy steels are competitors with the more familiar, earlier carbon steels. High speed tool steels have been known for some time. Their introduction has effected great economy in machine tool operations, at least in respect to the rapid work which such tools are capable of performing. The ultimate economy is sometimes menaced by the condition imparted to the machined members. The objections which have been urged against punching and shearing also apply to steel members after very heavy chips and feeds have been taken, such as are possible in the use of blue-chip tool steels.

Alloy and heat treated steels are presenting themselves as candidates for favors in other lines of engineering. The automobile industry has stimulated effort in this direction on account of the saving in weight of steel by calling upon it to endure higher fiber stresses. In airplane work the saving in weight is of greater consideration. In the latter line of construction, however, it is not pleasant to contemplate the consequence of subjecting the working parts to endure higher fiber stresses than the metal is capable of sustaining over periods of long duration, the particular feature upon which primitive tests on physical properties do not afford sufficient data.

These remarks will hardly be considered as an enthusiastic endorsement of the indiscriminate treatment of steel, conducted without a full realization of the gravity of the features involved. Suspending a one-ton weight from a slender wire furnishes a forceful illustration of the fiber stresses which are involved when steel is loaded to a maximum. It only represents, however, the stresses which a comparatively small range in temperature is capable of introducing in steel. The control of so powerful an agency as heat demands the utmost skill and painstaking care.

Steel music wire of a fine size, No. 12 music wire gage, has been found to show a tensile strength exceeding 450,000 pounds per square inch. This wire when released from tensile stress, prior to rupture, would be capable of a resilient recovery of not less than 15 thousandths of its length. It represents the maximum range in elastic extension and recovery which has come to the knowledge of the speaker. This wire, in the upper octaves of a piano-forte, is stressed 150,000 pounds or more

per square inch, representing an extension of 5 thousandths of its length. Music wire is a carbon steel of about 0.85 per cent carbon. Its high strength is acquired as the results of drawing through several numbers without annealing.

In compression, hardened steel has been found to sustain a stress of 600,000 pounds per square inch, representing a compressive strain of 20 thousandths of its length. Failure of this specimen occurred by reason of the bursting of the reinforcing buttresses, throwing an eccentric stress on the hardened center. The radial extension of the specimen, according to Poisson's ratio should be in the neighborhood of 6 thousandths of its diameter. In this comparison of the maximum elastic extensions of steel it appears that the direct extension in the music wire presented a higher value than the indirect, radial extension of the compression specimen.

As to the effect of cubic compression on steel, that is, compression applied in three directions simultaneously, the highest pressures reached in experiments conducted by the writer caused no appreciable permanent effect. Pressures up to 117,000 pounds per square inch were employed. These experiments were made in a hydrostatic press having thick walls. The temporary reduction in volume of the steel, if such occurred, was too small to be determined. Carefully boiled water when under this high pressure was reduced in volume over 15 per cent.

So far as known cubic compression of any degree is without permanent effect on steel. Even a sample of Portland cement was unaffected by a stress of 100,000 pounds per square inch cubic compression. These observations, so far as they went, confirmed the belief that loss of integrity of steel is the result of excessive tensile strains between adjacent particles; that efforts to force the particles closer together result in no permanent changes in physical properties.

Alternate stresses of tension and compression present quite another problem over those of stresses in one direction only. It has not been possible to realize the high values displayed by the metal in the individual tests of tension and compression. In fact, only about one and a half thousandths elastic movement in each direction, or three thousandths aggregate movement has been found in the case of repeated alternate stresses, for periods of long duration. Stresses in certain grades of steel in repeated alternate stress tests have been endured for 100 to 200 million repetitions, under loads up to 45,000 pounds per square inch. Under higher fiber stresses the number of repetitions of stresses which caused rupture was much less.

A repeated alternate fiber stress of 45,000 pounds per square inch appeared to be the limiting stress for indefinite endurance using carbon steel bars of different carbon contents, ranging from 0.10 to 1.00 per cent carbon and regarding 200 million repetitions as equivalent to indefinite endurance. The feature was not fully established but there were indications that a saturated steel, in reference to its carbon content, about 0.90 per cent carbon, possessed greater enduring qualities than steels of higher or lower carbon. These tests were conducted a number of years ago. They were inaugurated 33 years ago, and some 400 bars were tested under different fiber stresses at normal and at high temperatures, puddled iron, cast iron, hot rolled and cold rolled steels being included in the series. A steel bar of unusually high elastic limit, acquired by heat

treatment did not on that early occasion show superior endurance to the plain hot rolled steels. It has been said in explanation of those results that heat treatment in early days was not as well understood as at the present time.

Notwithstanding the fact that the elastic limits of the experimental bars used in the repeated alternate stress tests were considerably above the fiber stresses employed in many of the tests yet it was found that prior to rupture some slight permanent sets were displayed in each case. As the limiting number of alternate stresses was approached, the bars showed permanent deflection sets, which increased toward the last. These deflection sets amounted to but few thousandths or 0.010 inch on a chord of 10 inches. Their presence, however, raised an interesting query, whether they were not indicative of some intercrystalline strain, and through their presence led to a higher local strain than the fiber stress on the test bar called for. In other words, the question was raised whether the steel was actually ruptured by a reduced fiber stress or whether some state of internal strain did not contribute toward rupture by an intensification of the nominal strains within the steel.

It was found that steels ruptured by repeated stresses while at a blue heat endured a much greater number of repeated stresses than the same steels when tested at atmospheric temperatures. It had also been shown in an earlier series of tests, made at different temperatures, that the steels were stronger at a blue heat than when cold. Their greater endurance at a blue heat seemed to connect the value of the tensile strength with durability of the steel, although the apparent fiber stresses were below even the primitive elastic limit.

Another feature of interest was brought out in these tests and those of another character conducted in those early days. It appeared that exhaustion of ductility preceded actual separation or rupture of the steel under conditions of repeated stresses and also when subjected to the cold rolling action of wheel pressures. This is a matter which is regarded as of importance. It suggests the possibility of restoring the steel to its primitive state and prolonging the endurance of repeated stresses. As entertaining as this thought was, efforts at that time did not bring about a favorable result. Provided a steel bar will endure a certain fiber stress for 100 million repetitions before rupture, it is of interest to ascertain whether the progress of rupture admits of being arrested at some intermediate stage, the steel being relieved of its internal critical condition and renewed. Its ductility admits of restoration. The annealing of iron chains is an example. The question therefore is whether a process which is capable of restoring ductility is also capable of restoring the steel from the effects of repeated stresses, renewing its primitive ability in the endurance of repeated stresses.

In hot worked steels there is substantially an equality in the elastic limits of tension and compression. A series of experiments was conducted on the effects of overstraining steel bars by alternate tension and compression, not as a beam is strained by alternate bending loads, but by applying direct loads in an axial, longitudinal direction. The total elastic range in stress, tension plus compression, without loading beyond the elastic limit in either direction, amounted to 100,000 pounds per square inch. This range was curtailed upon overloading the bars in either direction. Overloading in either direction greatly impaired the value of the elastic limit in the opposite direction, reducing the total elastic range. The observations were not conclusive as to whether time without change in temperature, effected a restora-

tion in the values of the two elastic limits, of tension and compression respectively.

It has long been known that a temporary reduction in the modulus of elasticity occurs in overstrained steel, from which there is a recovery after the lapse of time. Ascending and descending stress-strain curves in overstrained steel follow different paths. There is an area of lost work shown by the diagram which must mean that a state of internal resistance has been caused by the overstraining loads, while the recovery from this state indicates a probable molecular readjustment within the steel.

The behavior of lead furnished a suggestive illustration, but one which has not been detected in steel, although perchance research has not gone far enough to do so. It is as follows: A lead cylinder taken from a pig with the axis of the cylinder coinciding with the longitudinal axis of the pig, when upset endwise displays a greater tendency to flow radially in the direction of the major axes of the lead crystals. The result of upsetting is an elliptical shaped specimen, but this occurs when the upsetting is continuous. Providing a partial upsetting is given the cylinder followed by an interval of rest after which the upsetting is renewed, the result is then different. The cylinder now presents about the same tendency to flow radially in each direction, and further upsetting results in forming a specimen substantially of circular cross section. Overstraining followed by an interval of rest has changed the properties of the lead crystals*

Annealing results in a pronounced change in the dimensions of a steel forged or rolled shape. The successive annealing of a section of a steel rail, at 1500 degrees Fahr. caused a shortening of its length, which referred to a 33-foot rail amounted to nearly 1.2 inches. These observations were extended to the effects of annealing a cube taken from a forging. The cube contracted, when annealed, far more in the direction in which it was drawn out in the forging than in its other two dimensions. These observations made with a strain gauge revealed a movement which was unexpected, at least by the author. Other observations on the effects of quenching steel from a high temperature made at this time showed the difficulties which are experienced in operations of this kind in maintaining the shapes of hardened and annealed steel members unaltered. It is impracticable to quench a uniformly heated cube and preserve the fixed relations which the sides of a cube bear to each other. The different sides and edges each are differently affected when plunged into the quenching bath.

The difference in the rate of transmission of strains and the rate of conductivity of heat is a pronounced factor in the heat treatment of steel. The dilation of the metal by heat lags much behind the prompt transmission of strains. A proper realization of these differences which prevail is of advantage in conducting the heating, quenching and drawing of steel shapes.

Internal strains result from heat and mechanical treatment. The magnitude or saturated state of the internal strains is doubtless limited by the elastic limit of the steel. Higher internal strains have been observed as the result of heat treatment than those caused by mechanical means. The acquiring of internal strains by steel probably is associated with changes in density of the metal. The only known method of determining either the presence or magnitude of internal strains is to machine-cut the steel into small detached parts and note the changes in dimensions which then occur. It is, of course, known that internal strains will result from a variety of

*Editor's Note:—Strained lead recrystallizes slowly at room temperature.

treatments but in the absence of information upon antecedent conditions inspection of the steel does not indicate whether or not strains exist therein. In respect to microscopic examination it is not discernible whether the steel is in a state of repose, or whether in a state of internal tension or compression. The great value which would attach to a method of examination by means of which the internal state of strain of a steel member in place could be determined is apparent. Such a method would enable the strains which exist in all kinds of engineering structures to be ascertained and the margin of safety to be judged.

So far as known there is no difference metallurgically or physically between internal strains which result from certain ranges in heat or mechanical treatment and those which are due to external loads. If such is the case, then rupture may be accomplished either by heat, mechanical means, the application of external loads, or by their combined action. Cold rolling which distorts the grain of the steel and drastic heating and quenching which changes the microstructure represent extreme conditions which qualify this statement.

From the point of view which a consideration of the influence of internal strains leads to, it seems logical that heat or mechanical treatment is a step in the direction of ultimate rupture. It is quite certain that heat treatment is capable of causing spontaneous rupture and examples of such effects are by no means uncommon. The effects of heat treatment are effaced in whole or in part by annealing. Annealing also relieves the steel of internal strains. The essence of heat treatment appears to reside in the introduction of internal strains in the steel. It is a serious question to what extent such treatment is desirable and the purpose for which the treated steel is to be used. Such a question might best attach to airplane construction, where the penalty of failure is most obvious.

The question may be asked: What is the peculiar state of a steel which has had properties imparted to it foreign to its natural, annealed condition. Such steel, it is known, has a state of rigidity and superior strength under stresses once applied, twice applied, and it may be thousands of times. There are situations, however, in which the stresses are repeated millions of times. Steel which fails in service does not commonly display the properties witnessed in the original tests. It fails in service without display of ductility showing neither elongation nor contraction of area comparable to the original test. Brittleness, almost extreme, is characteristic of service fractures. This circumstance leads to the mental association of internal strains, their localization, and their influence on the ultimate rupture of steel in service.

Heat treatment admits of being employed covering a wide range in temperature, with pronounced effects whether temperatures above or below the critical points are utilized. Certain phenomena are associated with the recalescent points, apparent in changes in structure. At plastic temperatures steel is hardly capable of retaining internal strains of magnitude and at such temperatures it possesses a very low tensile strength. Notwithstanding a diminished value of the modulus of elasticity, the strain between adjacent particles necessary to cause rupture while the steel is at a plastic heat, is of low degree. There is a feature in this connection which is worthy of consideration. It concerns the ability of the steel to endure differences in temperature at plastic temperatures with special reference to the interior portions of the steel. A state of cubic extension is set up at certain stages in the cooling of steel shapes; cooling strains of tension then act simultaneously

in three directions. The result may be a separation or shattering of the interior metal as witnessed in the case of steel rails with shattered zones in the head and at the junction of the web and base, or the steel may be left in a state of strain without actual rupture having been reached.

Ordinary cooling of forged or rolled shapes in a way constitutes heat treatment and internal strains may be thus introduced which are equivalent to stresses amounting to thousands of pounds per square inch. Quenching from comparatively low temperatures has been tried to introduce internal strains in hollow forgings. Internal strains were introduced at the bores of tube forgings equivalent to stresses of compression from 30,000 to 40,000 pounds per square inch. A favorable disposition of internal strains was thus accomplished for the resistance of interior pressures in thick hollow cylinders, provided subsequent use did not involve exposure to high temperatures. In a gun, however, exposure of the bore to the temperatures of combustion of powder gases at once annulled the initial advantage of the internal strains. The metal at the bore of a gun acquires a state of internal tension as the result of firing a few rounds. Heat treatment of this kind to improve the elastic resistance of the tubes of guns was a futile effort. Service conditions effaced the results which had been accomplished by the operation of quenching. Quenching from the bore of the powder chamber of the barrels of small arms was so drastically performed that the metal acquired a state of extreme hardness, leading to premature bursting of the barrels.

In the heat treatment of large forgings, hollow boring generally is stipulated. This is done in recognition of the introduction of intense internal strains by the operation of quenching. Heat treated driving axles have been put into place in which the internal strains caused a critical condition, the steel being in a state near to spontaneous rupture. Driving a plug in the end of such an axle, to afford opportunity of centering the axle in a lathe, overcame the residual strength of the axle whereupon it split into four equal sectors. This occurred in a hollow bored axle of about 10 inches diameter. Heat treated axles are received with distrust by some railroads since instances have been reported, seemingly well substantiated, where failure has taken place in driving axles at a very early period. Locomotives with heat treated axles have been delivered and in some cases the driving axles are reported to have ruptured before the engines had been taken over the tracks of the receiving company. Star-shaped fractures witnessed in heat treated steel rails at the junction of the web and base, partially destroyed the rail and rendered it unsafe for use.

It hardly can be gainsaid that subjecting steel to violent changes in temperature is not attended with elements of danger. Enormous forces are being dealt with, which must be kept under proper control. The rays of the sun sway colossal structures, buildings and bridges which sustain or suspend millions of pounds of material. A few degrees difference in temperature does this. The range in stresses involved in such engineering examples amount to but a few thousand pounds per square inch. In the heating and quenching of forgings of steel the mechanical equivalents of the heat effects are very great. It is to be hoped that more definite information may soon be acquired and become available concerning what constitutes the elements of durability to endure the vicissitudes of steel in service.

In conclusion does it not appear that points of similarity may be found between steel and good physique in a person, the resemblance extending to heat treatment of steel and highly developed physical culture in the

individual, with this sequel that an overstrained athlete while possessing great temporary prowess lacks endurance. Steel may be presented in any state, from one of internal repose in annealed metal to that of extreme internal tension in hardened metal, it then being on the verge of spontaneous rupture. Between these extremes there is a wide field within which the operations of heat treatment are conducted. The basic problem is found in the query: In what state does the steel best meet the conditions of service, which generally have to do with the endurance of long continued strains?

The heat treatment of steel precipitates this question.

THE BESSEMER PROCESS FOR MAKING STEEL

By Arthur P. R. Wadlund*

(A Paper Presented Before the Hartford Chapter)

Previous to about 1850, steel was made by both expensive and slow processes and no method was known whereby a large quantity of steel fit for commercial use could be produced. It will be remembered that crucible steel, for instance, is produced only in lots up to 100 pounds as a maximum, some lots being as low as 25 pounds. About that time an American named William Kelly and an Englishman, Henry Bessemer, worked out a method almost concurrently but independently for accomplishing quantity production. Although Kelly did not apply for his patent until 1857, almost two years after Bessemer's English patent was granted, his application was allowed on the grounds of priority, because he was able to prove that he worked out the idea as early as 1847. Lacking financial means, however, Kelly was unable to perfect his invention and after much litigation with Bessemer interests a settlement was made whereby Kelly dropped out of the game. At first Bessemer accidentally employed only Swedish iron which had a low phosphorus and a high manganese content and he was very successful in converting it. But although adopted by many manufacturers, the process failed when applied to English irons, which were high in their phosphorus and low in their manganese content, and prejudice and opposition to the method became so great among steelmakers that to save the process Bessemer was obliged to build a steelworks himself. His plant built in Sheffield began to operate in 1860. The history from that time on is merely a history of improvements which have been introduced in detailed mechanical arrangements and larger appliances.

Of all the processes for the purification of pig iron, that is the making of steel, the bessemer is the simplest. Essentially it consists of blowing air under pressure through a bath of molten metal contained in a vessel constructed of proper refractory materials. The principle involved is the same as with every process for making steel; the elimination of impurities by oxidation. To say every process relies on oxidation for the removal of these impurities is not quite correct in this age of electricity, for the electric furnace process involves both oxidation and reduction.

The distinction between these processes lies in the method of oxidation. In the bessemer, the oxygen for the oxidation comes from the air supplied by the blast. Oxidation is accompanied by heat and it is this heat resulting from the oxidation of the impurities that is depended upon to keep the metal in a fluid state.

At this point we must distinguish between the two Bessemer

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methods; namely, the acid bessemer and the basic bessemer, or Thomas Gilchrist method. This is necessary because the chemistry of the two processes is different. In the acid process only silicon, manganese, and carbon, together with some iron are oxidized; whereas in the basic process the silicon, manganese, carbon and phosphorus, together with some iron, and sulphur, are oxidized. Furthermore, in the acid process it is the oxidation of the silicon which is depended upon to furnish a large portion of the requisite heat, while in the basic it is the phosphorus which is depended upon. Thus in the acid process neither the phosphorus nor the sulphur are reduced and we must use a pig iron which contains no more of the two elements than the final product will permit, usually about 0.10 per cent phosphorus and 0.08 per cent sulphur as a maximum. In the basic process, on the other hand, we must use a pig iron of high phosphorus and a low sulphur content; low sulphur because it is eliminated only to a limited extent, and phosphorus over 2 per cent for the reason given above, that is, to furnish the requisite heat.

The bessemer process is therefore applicable only to two kinds of ores: First, those containing only a trace of phosphorus giving an iron suitable for an acid process; and second, those containing a high percentage giving an iron containing two per cent or more of phosphorus and suitable for the basic process. Many deposits of ore exist in different parts of the world which are intermediate between these classes and which give an iron ranging from 0.1 up to 2 per cent. Although these ores are not suitable for either form of bessemer process, it often happens that an iron which contains too little phosphorus for the basic converter can be used in admixture with an iron that contains a surplus. When this is impracticable such irons can be used for steel only in the basic open-hearth furnace.

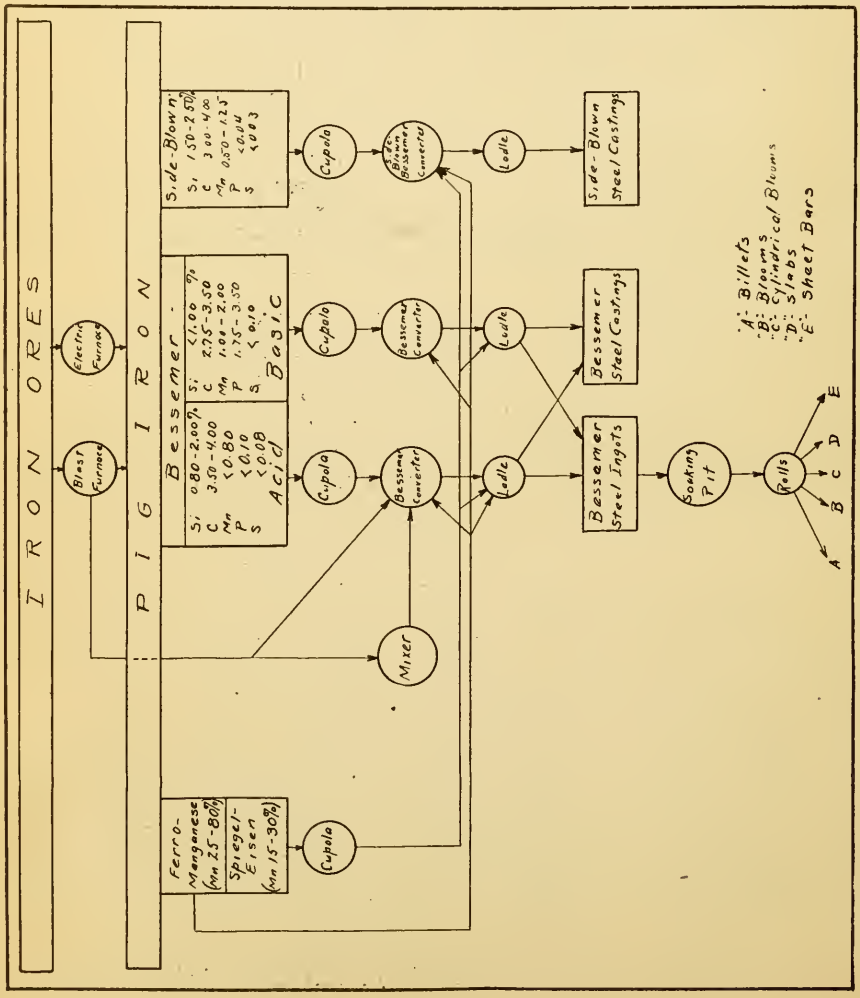
The apparatus in which the purification of the pig iron takes place is a pear or egg shaped object called a converter. At first the converters were stationary and the air was delivered through tuyeres in the side, from which the name "side-blown converters" was derived, with the finished metal delivered through a tap hole in the bottom. Owing to the difficulties in quantity production this method gave way to the "bottom-blown converter" in which, as the name implies, the air is admitted through tuyeres in the bottom. Evolution in the bessemer process led to the construction of the converter in three parts: namely, the bottom, the body, and the nose, also to the adoption of a tilting rather than a fixed unit. If the nose is symmetrical with the axis of the converter it is said to be "concentric"; if off center, it is "eccentric". The tilting converter is supported by two hollow trunnions, one of which has connected with it a pinion actuated by a toothed rack to allow for tilting, while the other forms the connecting link between the blast line and the blast box.

This blast box is situated directly beneath the bottom. It is very important that the bottom plate of the box should be easily removable so that the tuyeres may be easily examined and repaired or renewed, and at the same time it must be perfectly air tight, to prevent a waste of blast. The air for the blast is usually supplied by a high-pressure, double-cylinder blowing engine. The blast pressure, of course, depends upon the size of the converter and the head of metal to be overcome. It is customary to use about 20 pounds pressure per square inch.

From the blast box the air passes into the bath through tuyeres. In the acid process these tuyeres are made of refractory brick from 20 to

26 inches in length with holes from ⅜ to ½ inch in diameter. In the basic process the tuyeres are formed by ramming the refractory around wooden pins which are withdrawn after firing. The total tuyere area varies from 2 to 2½ inches per ton of charge. The charge varies from 5 to 25 tons with 15 as a good average. At this point it hight be well to mention that stationary and side blown converters are still used in units such as 5 tons or less, especially in steel foundries in America, and steel-works in Sweden.

The inside of the steel converter shell is lined with a highly refractory material, varying in thickness from 10 to 16 inches for different parts, being thickest on those parts subject to the greatest wear. The bottom, because it contains the tuyeres, is subject to the greatest hardships and therefore must be replaced most often. The life of a bottom depends upon the heat of the blows, the length of the blows, the blast pressure, and the amount of manganese in the pig iron. A bottom is generally worn away in about 12 to 15 blows, and sometimes fewer, while the lining of the body



Tracing Iron Ore to Finished Product by the Bessemer Process. Chart in Part by Frank E. Sanborn

of the converter lasts from 3 or 4 to 12 months or more. The nose lasts longer than the bottom but much less than the body. From what has been shown above, the advantage of making the vessel in three detachable parts is clearly evident.

In the acid process, the lining is made principally of silica, which is a highly refractory acid material. In England ganister rock, a high grade silicious material, and in America ganister, fire-stone, of mica-schist, with a thin layer of refractory fire clay laid between is used. These linings are thoroughly dried and brought up to a red heat before the converter is charged with molten pig.

The molten metal for supplying the converter may be (1) melted in cupolas, (2) taken direct from blast furnaces, or (3) taken from the latter and passed through a mixer before finally passing into the vessel. If, according to the first method, the molten iron is taken from the cupola, it may be poured directly into the converter by runners; it may be poured into a ladle on the same ground level as converters; or it may be tapped into a ladle on the ground level and the ladle then raised and the metal poured into the converter. From an economic point of view, both as regards labor and fuel, the ideal method is the second named, that is, to take molten iron direct from the blast furnace to the converter and so save the cost of remelting in a cupola. Owing to the irregularity of composition of such metal it has been discontinued in most cases.

To get a metal of more uniform composition it is almost universal practice to resort to the third method. For example, the molten iron from a number of furnaces is poured into a large vessel known as a mixer or receiver, as stated. These mixers have a capacity as high as 1200 tons and are made of steel plates riveted together and lined with silicious material, so constructed that they may be tilted and the iron poured from them into the converter. When receiving a charge the converter is always in the horizontal position.

Immediately after the vessel has received its charge, the blast is turned on under a pressure sufficient to prevent the metal not only from flowing into the tuyeres, but also to force the metal through the liquid. The converter is then racked to the vertical position and the blow commences which starts the chemical action between the oxygen of the air blast and the various ingredients.

The blow may be considered as divided into three stages or periods. First, the slag forming period; second, the boil; and third, the finishing period. During the first period the greater portion of the manganese and silicon are oxidized and unite with some oxide of iron—which is simultaneously produced—to form a double silicate of iron and manganese slag. Under normal conditions carbon is not appreciably oxidized until a considerable portion of the silicon has been removed. Such carbon as is oxidized passes off as carbon dioxide. This period is marked by an irregular violet colored flame at the mouth of the converter, gradually becoming more steady and then changing to a yellow color as the temperature of the bath increases.

After 5 or 6 minutes the carbon begins to oxidize rapidly and the bath being very fluid owing to the high temperature produced by the combustion of a relatively large proportion of silicon, the second period known as the boil commences. During this period the oxidation of silicon and manganese continues and a greater part of the carbon is also removed, mostly in the form of carbon monoxide, the percentage of carbon dioxide

forming rapidly decreasing. It is the formation and escape of carbon monoxide which causes the violent agitation of the bath and is attended with a very large flame issuing from the mouth of the converter, also with the ejection of considerable quantities of metal and slag. During the last period, the small amount of silicon left and the remainder of the carbon are oxidized, the latter to carbon monoxide. At the end of the boil the flame at the mouth of the converter rapidly contracts and the final disappearance of carbon is marked by the drop of the flame which indicates that the blow is complete. The vessel is immediately turned down and the blast shut off. In all, less than 20 minutes have elapsed. It is the judgment of the blower which is depended upon entirely to say when the blow is completed.

As was stated the phosphorus and sulphur in the metal are not eliminated. This is because the acid slag will not dissolve them even if they become oxidized. For this reason the percentage of these impurities increases slightly during the blow because their actual weight remains the same while the weight of the bath decreases. For instance, the total loss during a blow will amount to something like 8 to 10 per cent of the charge. Nearly half of this is oxide of iron and manganese which can be recovered by using them in the blast furnace.

The composition of the metal at this stage is about as follows:

Carbon	0.03-0.10 per cent
Manganese	trace-0.06 per cent
Silicon	trace
Sulphur	0.03-0.06 per cent
Phosphorus	0.08-0.10 per cent

If this metal were cast into ingots and rolled, it would be red short, that is, it would crack when rolled at a red heat. To overcome this red shortness a recarburizer is added. When mild or dead soft steel is being made ferromanganese or ferro, the best grades of which it will be remembered contains about 80 per cent manganese—usually is employed. This is thrown into the converter cold, or in some instances first heated to redness. When a high carbon steel is required, such as rail steel, spiegeleisen or spiegel containing about 30 per cent manganese—in the best grades—is used. This is always melted in a cupola and added in a molten state either in the converter or the ladle. Spiegel is added in a molten state because the quantity required to give the requisite manganese in the finished steel would often be more than the bath of the molten metal would be able to melt.

Although the percentage of manganese is very different for ferro and spiegel, the carbon is nearly the same. Consequently, the addition of say 100 pounds of an 80 per cent ferro and 400 pounds of a 20 per cent spiegel, although giving the same amount of manganese, would give very different amounts of carbon, the latter four times the quantity of the former. From this it is evident that when the carbon is to be raised without increasing the manganese to any considerable extent, it is cheaper to use a large quantity of spiegel rather than a smaller amount of more expensive ferro. Anthracite coal, ferrosilicon (10 per cent silicon), and pig iron are also used in special cases as recarburizers. In addition to recarburizing, the recarburizer deoxidizes; that is, any iron oxide which is held is oxidized by the manganese and carbon. In the former case the oxide of manganese goes into the slag and in the latter case the carbon monoxide goes off as a gas producing a "boil" which requires precaution-

ary measures. This reaction is usually referred to as the spiegel or ladle reaction.

If the recarburizer has been added in the converter, the vessel is tilted beyond the horizontal position and the metal poured into a ladle. This ladle is then taken to the pouring platform. Here the teeming hole in the bottom of the ladle is opened and the ingots, or castings, poured. It should be noticed that in this operation of casting, the metal is teemed, whereas it is poured in the case of the converter and mixer. The reason for this is that we are not much concerned with the disposition of the slag, except when a finished or semifinished product is concerned, such as these castings or ingots mentioned.

If the recarburizer is not added in the converter it is added in the ladle. After the action has ceased, the ladle is brought to the platform and the ingots or castings poured as before. When castings are made we have a finished product and reach the end of the process. On the other hand, when ingots are poured, they must go first to a soaking pit and then to the rolling mill before the finished or semifinished product is produced.

Before passing to the basic process, let us examine the ingot molds. These molds are made of cast iron, the shape of which may be almost any convenient form or size, the purpose for which the steel is required being the determining factor. Ingots may be either top poured or bottom poured. Moderate sized ingots, say 10 inches square, are generally top cast. Bottom casting usually is employed only when a large number of small ingots are desired. The tendency of late years, however, has been to cast larger and larger ingots and cog down to blooms in the mill, finally rolling these to the required sections.

Before going to the mill, the ingots must be stripped of their molds. For this purpose the ingot stripper is used and is a very important adjunct There are many forms of strippers, but perhaps the simplest and most used is the one which consists essentially of three rams, the outside rams pulling up on the molds to which they are attached, while the center ram acts as a plunger to hold the ingot down. The stripper not only saves a considerable amount of labor, but also reduces the cost of molds which would be short lived when pounded with the sledge. As it is, a mold stands only 100 casts at the most, 50 being a good average.

Let us now take up the basic process. We are all familiar with the quotation that "necessity is the mother of invention," and surely this applies to the invention of the basic bessemer process. As has been shown, the acid process removes no phosphorus and we have also seen that there are large ore deposits from which to produce a pig iron high in phosphorus. It was the utilization of this pig iron to which Sidney Thomas with the assistance of his cousin, Percy Gilchrist, lent his indomitable energy, ultimately both successfully, and completely solving the problem in about 1875. As a result the basic bessemer process usually is spoken of as the Thomas-Gilchrist process.

The secret lay in the substitution of a basic for the acid lining and the addition of a basic flux. Thus the silicious material used in the acid process is replaced by a lining of shrunk dolomite or other basic material rammed with anhydrous tar, and the basic material added is lime. The lime allows the formation of phosphate of lime which is not decomposed by metallic iron at the high temperature of the converter, and practically the whole of the phosphorus present is removed in combination with the lime

in the slag. If an acid lining were used rather than the basic, the acid lining would be attacked by the basic slag and eaten away before the end of the blow. Theoretically the basic lining plays no part in the reaction, only in so far as it provides a nonsilicious lining and enables a very basic slag to be formed by the lime addition.

The converter having been thoroughly heated, either by a previous heat or by means of a coal or coke fire as in the acid process, the lime is shoveled into the converter, which is in the horizontal position. Immediately the molten metal from the blast furnace, mixer, or cupola is admitted, the blast turned on and the vessel racked to the vertical position.

The various stages of the blow are identical to those described in the acid process until the drop of the flame which corresponds to a point where the carbon is reduced to about 0.05 per cent as has been said above. From here on comparison ceases. In the acid process we have seen that the vessel is immediately turned down and the blast stopped, but in the basic process the blast is continued for 3 or 4 minutes. This period is termed the "after blow" and is an absolute necessity because it is during this time that practically all of the phosphorus and some of the sulphur is removed, that is, we have the great heat forming period. The judgment of the blower is again depended upon for the determination of the end of the blow. His judgment as to the purity of the metal is based upon fracture tests on small samples.

In an earlier part of this article we accounted for the removal of the phosphorus. However, when we come to account for the behavior of the sulphur during the blow, we find it somewhat difficult because it is erratic. Sometimes considerable is removed, while at other times the elimination hardly is perceptible. The charges high in sulphur seem to have a greater percentage removed than those low in this element. The exact reactions will be omitted because authorities differ. It might be stated, however, that the fluid basic slag is generally conceded to be the main factor in the elimination of sulphur and also that manganese, after the addition of either ferro or spiegel, seems to play some part.

In passing, it might be well for us to get an idea of the amount of lime required. This depends upon three conditions: First, the amount of silicon; because silicon which is oxidized during the first few minutes of the blow is acid by nature and would attack the basic lining if it did not have the lime to satisfy it, which means that in adding lime we must account for the silicon content of the pig; second, the amount of phosphorus in the pig, because the phosphoric acid (P_2O_5) which is formed reacts with the lime to form phosphate of lime; third, the quality of the lime, for it is self evident that it should be as free from silica as possible, in fact a content of more than 1.5 per cent is very undesirable. Taking all three facts into consideration, it is necessary to add lime to the extent of from 14 to 20 per cent of the molten pig charged.

When ready to pour the metal, the following composition obtains:

Carbon	trace
Manganese	trace
Silicon	trace
Sulphur	0.05 per cent
Phosphorus	0.08 per cent

This analysis is not far different from the acid metal at the same stage. Following the same reasoning then, ferro, spiegel, etc. must be added, serving as before both as a recarburizer and deoxidizer. However,

this recarburizer is not added in the converter because the carbon monoxide at this time is liable to reduce the phosphorus from the slag and cause a rephosphorization of the metal, inasmuch as carbon has a greater affinity for oxygen than has phosphorus. It is found best to pour off as much of the slag as possible before the metal in the converter is poured into the ladle where the recarburizer is added. Basic slag is more fluid than acid slag because of the greater quantity of manganese in basic pig which is oxidized. From this point on there is no difference between the two processes.

If we compare the basic process with the acid process we will see that the former is much more expensive: First, because of a longer time in the blow; second, because at the end of the operation there is a delay to test for dephosphorization; and third, the greater cost of repairs, inasmuch as basic linings cost more than acid, but last only a fraction as long. However, this greater expense is partly equalized because basic pig is cheaper than the acid pig at least in the United States and also because high phosphorus slag may be sold as a fertilizer. In this country the basic process is no longer in operation, except to a very limited extent. The Germans on the other hand, with their immense deposits of high phosphorus ores of the Minette district found this process of incalculable value.

CARBONIZING AND CARBONIZING MATERIALS

By H. B. Knowlton*

(A Paper Presented Before the Tri-City Chapter

Carbonizing steel is the process of adding carbon. Steel may be carbonized during its manufacture, or it may be partially carbonized in the case hardening process. In this article only the carbonizing that forms a part of the case hardening process will be considered.

Steel may be case carbonized by any one of three ways: (1) By immersing the steel in a melted bath of cyanide or some similar bath. Sprinkling with a cyanogous material is really one phase of this same method. (2) By packing the steel in boxes with some solid carbonaceous material. (3) By gas carbonizing.

Cyaniding is one of the oldest or most commonly used methods. In general, it is used only in the production of very thin cases. It is known that the cyanides tend to break down under heat and yield cyanogen or some derivative of cyanogen. Cyanogen is a compound containing carbon and nitrogen. It has been believed generally that when cyanogen reacts with the steel, the carbon combines with the steel and the nitrogen liberated has no actions at all. It is worth noting, however, that G. R. Brophy and Miss S. B. Leiter of the General Electric Co., Schenectady, N. Y., presented a paper at the Philadelphia convention on "The True Action of Cyanide in Case Hardening Steel," in which they showed that the nitrogen of the cyanide did combine with the steel. This paper was published in the March issue of TRANSACTIONS. The authors claimed to have produced steel file hard, which contained only 0.30 per cent carbon at the surface.

In this steel they found large quantities of nitrides of iron, that is, combinations of nitrogen and iron. Hence, they argue that it is the nitrides and not the carbon in the steel that caused the hardness. They further bring out that steel containing nitrides is more brittle and more liable to surface

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cracks than steel truly carbonized. If their work is correct, then it must follow that cyaniding has certain disadvantages and probably should be used only in the production of very thin cases on comparatively unimportant parts. Also, that it may be well to do away with the practice of reheating tools in cyanide.

Gas carbonizing is a comparatively new process. It has some advantages but at present seems to be limited to certain classes of work. The common type of gas carbonizing furnace is the revolving retort. The steel is placed inside of the retort and a current of gas is passed through while the whole is heated to a carbonizing temperature. As a general rule some carbonaceous material such as used in bone, leather, or old carbonizing compound, is charged into the retort along with the work. This is to cushion the work as it turns over and prevent mutilation of the hot pieces. By this method the time of carbonizing can be reduced greatly. It is worth noting that this method has been operated without the stream of gas, in other words, the work was heated in the revolving retort in contact with a solid carbonizing compound. Again the time of carbonizing was greatly reduced below that of the ordinary pack hardening method.

This method opens up a rather new field but it seems to offer great possibilities. In many cases the lack of a plentiful supply of good rich gas makes gas carbonizing impracticable but the use of the revolving retort with the proper kind of a compound may have great possibilities, but the author believes that a different compound should be used in this method than is customarily used in the pack carbonizing method.

In the pack carbonizing method, the steel is packed along with some carbonaceous material in boxes, and the boxes are heated for a number of hours. At first glance it would seem that the fundamental requirements of a carbonizing material would be that it contain a large amount of carbon. One of the questions frequently asked the makers of carbonizing compounds is "How much carbon does your compound contain?" While the question can be answered, the answer does not give much valuable information. For example, some grades of anthracite coal contain about 85 per cent of carbon, while bone contains only about 10-12 per cent carbon.. Yet it is well known that bone is a much better carbonizer than anthracite coal. It may be well therefore before discussing the compounds to devote a little attention to the carbonizing process itself, and to see just what actually happens when a piece of steel is carbonized.

One of the theories that have been suggested, is that solid carbon diffuses into steel with which it is in contact. We know that there is solid carbon in contact with steel in the carbonizing boxes, but we also know that there is a limited amount of air in the boxes along with the carbon and the steel. We know furthermore that in the presence of air, carbon will burn when heated to a carbonizing temperature, thus forming a gas, either carbon monoxide or carbon dioxide. Thus the question is, whether it is this gas or the solid carbon that reacts with the steel and this is really a very important question.

To determine the answer, it is necessary to carbonize with solid carbon under conditions which will not permit the carbon to burn or form a gas. One of the early experimenters tried this. He heated iron wire in contact with pure carbon in a stream of hydrogen. He argued that the hydrogen gas would prevent the carbon from burning and that it would not enter into the reaction itself, however, his work has been disputed. It has been argued that he

should have carried out his experiment in a vacuum. But the fact remains that while he did produce a very slow penetration of carbon, the penetration was so slow that this method of diffusion of solid carbon into steel cannot be considered a satisfactory explanation of the rapid penetration of the common carbonizing compounds. We must seek some other action than the diffusion of solid carbon.

Another theory in which many believed was that all carbonizing was a form of cyaniding; that rapid carbonizing was possible only with materials which contained cyanide or would form cyanogen when heated. It was argued that any compound that contained both carbon and nitrogen might form cyanogen. This would include such materials as bone and leather which were known to be rapid carbonizers, being better than charcoal or coal which contain a greater amount of carbon. Without going into the discussion as to whether the forming of cyanogen is the explanation of the action of bone and leather in carbonizing, let it be said that just as rapid penetration has been produced by materials which could not possbly form cyanagen. Giolliti showed for example that he could do good carbonizing with CO and CH_4 gases.

Most of the commercial carbonizing today is done with solid materials which could not be expected to form cyanogen. Thus while the formation of cyanogen may sometimes take part in carbonizing, it is not a necessary condition. Furthermore as already mentioned, if Mr. Brophy's work is correct, cyanogen may actually nitrogenize instead of carbonize the steel. It may be just as well to stay away from the compounds which contain nitrogenous matter. This is not said to criticize any compound on the market for as far as the writer knows, all of the makers of carbonizing compounds have already discarded the use of nitrogenous matter in the manufacture of their compounds.

The last theory and the one most commonly accepted now, is that the carbon burns to form a gas, carbon monoxide, and that this gas reacts with the steel. The carbon combines with the steel to form a carbide, cementite. Among other conclusions Giollitti states that, "All other things being equal, the concentration of carbon in the cemented zone increases when the quality of pure carbon monoxide which comes into contact with a unit surface of the steel increases." His data also shows that the depth of penetration also increased.

According to this theory a carbonizing to be efficient should yield as large an amount of carbon monoxide as possible when it is heated to the carbonizing temperature. This probably explains why coal which is slow burning is not as satisfactory a carbonizing material as charcoal which burns faster and consequently forms more gas. The organic materials such as bone and leather probably decompose somewhat at the carbonizing temperature and yield products which readily burn to carbon monoxide.

The acceptance of this theory is liable to lead to a rather dangerous conclusion—that it is not necessary for a carbonizing compound to be uniform; and that the gases will circulate evenly through the box and produce even carbonizing so far as one box at least is concerned. To prove that such is not the case, the author wishes to cite a personal experience. Several years ago he tried to make his own compound, using a formula derived from the analysis of the commercial material that he was then using. The method of manufacturing the home-made material was necessarily rather crude and probably the product was none too uniform. This material was run in direct

comparison with the commercial compound. Three test pins were placed in the top, middle, and bottom of each pot. After carbonizing, these pins were examined under the microscope for the depth of case and the distribution of the carbon, that is, for the depth of the different zones of the case. The results were as follows:

	Depth of Zones			
	Hyper-eutectoid	eutectoid	Hypo-eutectoid	Total
Pot No. 1 Bottom Pin	0.000	0.007	.032	.039
Pot No. 1 Middle Pin	0.000	0.017	0.036	0.064
Pot No. 1 Top Pin	0.000	0.017	0.042	0.059
Pot No. 2 Bottom Pin	0.007	0.021	0.031	0.059
Pot No. 2 Middle Pin	0.000	0.013	0.029	0.042
Pot No. 2 Top Pin	0.000	0.011	0.043	0.054
Pot No. 1B Bottom Pin	0.002	0.019	0.025	0.046
Pot No. 1B Middle Pin	0.007	0.012	0.034	0.046
Pot No. 1B Top Pin	0.000	0.015	0.038	0.053
Pot No. 2B Bottom Pin	0.005	0.015	0.028	0.048
Pot No. 2B Middle Pin	0.002	0.016	0.036	0.054
Pot No. 2B Top Pin	0.011	0.009	0.029	0.049

Maximum total depth of case in home-made compound 0.059 inch
Minimum total depth of case in home-made compound 0.039 inch
Maximum total depth of case in commercial compound 0.054 inch
Minimum total depth of case in commercial compound 0.046 inch

Attention is invited to the fact that the maximum variation in the depth of case appeared on pins in the same pot. The variation was 0.020 inch in the case of the home-made material and only 0.008 inch with the commercial compound. Both materials were complex compounds involving chemical energizers such as will be discussed later. This shows the necessity for the compound's being uniform. Various other proofs of the same fact could be given, but this one was chosen because the data was complete and conclusive.

The question arises; why if it is the gas that does the carbonizing, does a nonuniform compound cause nonuniform results in the same pot? The answer may be that some parts of the compound are giving off gas more vigorously than others, and consequently the concentration of the gas is greater at the particular places where it is being the most vigorously generated. Or there may be something in the fact that gases are more vigorous in their action at the time they are being generated than they are later. This is a well known phenomenon; that nascent or freshly generated gases are more vigorous than the same gases after standing.

The above test showed the variation in the case, on pins that were several inches apart in the same pot. Assuming that it is the concentration of the gas or the action of the nascent gas, would it be possible for nonuniformity of the compound to cause a variation in the carbonizing in very small distances? For example, would it be feasable to attribute a soft spot the size of a grain of corn to a lack of uniformity of the carbonizing compound? Or could a small lump of clay touching a piece of steel in the carbonizing pot cause a soft spot? The author is inclined to believe that neither is possible and that small soft spots must be explained in some other way. It may be possible to have a difference in the gas concentration in different parts of a large pot, due to the different rates of generating gas of different parts of a nonuniform compound, and also due to the slow passage of the gas through the tightly packed com-

pound from one part of the pot to another; but it seems highly improbable that there is a very great difference in the concentration inside of a small distance, say one inch or less.

This is answering the question from the theoretical standpoint. The same conclusion can be borne out by practical tests. For example, try to produce a soft spot at a given point by placing a small lump of dry clay against the piece at that point while packing it in the carbonizing pot. In some work on selective carbonizing it was found that it is not as easy to prevent the carbonizing gases from effecting particular parts of the steel, as is generally supposed. Copper plate and other thin protective coatings frequently fail to prevent carbonizing. In order to be sure that a given portion will not be carbonized, it must be covered with a coating that is absolutely impervious to gases at the carbonizing temperature.

These tests then lead us to the conclusion that a good carbonizing compound should yield a large quantity of carbonizing gas and that different portions of the same compound should generate the gas at the same rate of speed.

But these are not the only requirements of a good compound. The cost of the compound and the cost of new material that must be added to keep the compound up to strength, must also be considered. Another factor which is frequently overlooked is whether the compound adds anything injurious to the steel. The requirements of a carbonizing compound may be outlined as follows:

1. It must produce good results.
   - (a) Produce the desired per cent and distribution of carbon in the case.
   - (b) Produce uniform results.
   - (c) Must add nothing injurious to the steel.
   - (d) Produce good results at temperatures that are not harmful to the steel. A material requiring an excessively high carbonizing temperature, is undesirable.
2. It must be economical.
   - (a) Initial cost of compound per cubic foot should be low.
   - (b) Cost of upkeep of the compound should be low.
   - (c) It should give a rapid speed of penetration of carbon. When this is true the cost of operation of the furnaces will be comparatively low.
3. It should preferably be as noninjurious and as unobjectionable to the workmen as is practicable.

Some of these points are too obvious to need discussion, while others may be worthy of a little attention. Note that the cost must be figures per cubic foot. Compound is used by volume but is customarily purchased in weight. The different compounds vary in weight from about 17 pounds per cubic foot to over 50 pounds per cubic foot. One compound that is mostly saw dust is probably lighter than 17 pounds.

The cost of upkeep depends on the amount of new material that must be added after each run, either to keep the compound up to strength or to make up for shrinkage. Again it must be remembered that material is bought by weight but used by volume.

The question of adding injurious elements to the steel possibly is debatable. Bullens cites the work of Grayson which showed that by using leather he produced a case containing 0.55 per cent sulphur. The sulphur

content in the outer layer, 0.0025 inch, was 2.10 per cent. It is further stated that this high sulphur content of the surface causes softness and a skin brittleness or a tendency on the surface to chip off.

The use of cyanides and ferrocyanides in pack hardening compounds practically has been done away with, thus it is doubtful if there are any really poisonous compounds on the market. Some materials are rather disagreeable to the workmen on account of a large amount of dust.

Let us consider the different materials and see how well they fill the above mentioned requirements. Take first the older types of materials.

CHARCOAL. Charcoal probably is one of the first materials used. Wood charcoal is almost pure carbon with some moisture and a small amount of ash. The weight per cubic foot of granulated charcoal depends on the size of the granules and the kind of wood from which the charcoal was made. The size and kind of charcoal most frequently used in case hardening weighs about 19 pounds per cubic foot. It has a rather high shrinkage and it is not a very rapid carbonizer. It can be used over again but it has been stated that in the manufacture of blister steel it has been found that the charcoal is not as vigorous the second time as it was the first. Consequently it is necessary to add some new each time.

BONE. Bone carbonizes faster than charcoal and yields cases higher in carbon under the same conditions, but as bone contains only about 10 per cent of carbon it wears out very rapidly. Consequently, it is necessary to add a large amount of new each time, one half new bone being often considered absolutely necessary. Bone also contains considerable phosphorus, which is probably objectionable. Long tests have also proved that bone does not produce as uniform results as some other materials. This probably is due to the fact that the bones of all animals like the bones of the human change in chemical composition depending on the age and the condition of the animal. Bone weighs about 41 pounds per cubic foot.

LEATHER. Charred leather is another of the old standbys. It is very light, weighing about 17 pounds per cubic foot and has a rather high shrinkage. Leather has a good speed of penetration and produces cases high in carbon, but as mentioned by Bullens, leather may add sulphur to the steel. If it does that it is very objectionable. It has passed into disuse more on account of its high cost than any other factor.

COAL. Coal or coke probably have never been much used for carbonizing as they are both very slow. As will be shown, they have both been used successfully when mixed with other things.

So much for the raw materials that have been used in carbonizing. At the present time the socalled compounds have come into common use. The essential difference between these compounds and the raw materials is that the compounds are energized with certain chemicals, the idea being to increase the amount of carbon monoxide the compound will generate. Thus a chemical is added which when heated will give off either carbon monoxide or carbon dioxide gas. In either case in the presence of large amount of charcoal the final gas would be carbon monoxide. By the use of such chemicals wood charcoal and coke or coal can be energized until they will give a speed of penetration and yield a concentration of carbon in the case equal to that produced by bone or leather.

But if the chemical should spend itself with one time using, then more

chemical would have to be added after each run. Fortunately, however, there are some chemicals that are regenerative. For example, when they are heated they give off carbon dioxide but when they are allowed to stand exposed to the air after cooling, they will absorb the same gas, carbon dioxide from the air. In this way the chemical regenerates itself.

One successful compound on the market is composed largely of coal energized with lime. Most of the compounds use more or less charcoal. Some do not use coke, while a great many use more or less of this material. Nearly all the compounds utilize a chemical energizer. There is ground for some difference of opinion as to the proper amount of charcoal, coke and chemical respectively, some of the books give the following formula: charcoal 60 per cent and barium carbonate 40 per cent. So far as the writer has been able to learn, however, none of the commercial compounds in this country is made to that formula.

One pecularity noticed is that increasing the chemical content beyond a certain point does not seem to increase the speed of penetration of the carbon nor yet does it increase the per cent of carbon yielded to the case. As proof of this the following tables are cited. These were taken from a test made about a year and a half ago.

In this test four different mixtures of charcoal coke and chemical were used. They have been labeled mixtures Nos. 1, 2, 3, and 4. Mixture No. 1 contains the least charcoal and least chemical and mixture. No. 4 contains the most chemical and most charcoal. The others lie in between. Outside of the difference in the relative proportions there is no difference between the four mixtures.

Four pots of each mixture were placed in a carbonizing furnace together, the pots being staggered so as to give each material an even change. They were all run the same length of time and every means was taken to make the test as comparative as possible. In the top and in the bottom of each pot a test piece was placed. At the conclusion of the run, the pots were allowed to cool down and the test pieces were sent to the laboratory. The total depth of the case was measured and the carbon content at different depths from the surface was determined by actual chemical analysis on shavings from cuts taken on a lathe. The first cut extended 0.007 inch from the surface and the following cuts went deeper by 0.010 inch each. The results were as follows:

Total Depth of Case on Test Pieces
Millimeters

Mixtures Nos.	1	2	3	4
	1.0	1.2	1.3	1.1
	0.9	1.0	1.3	1.3
	1.2	1.3	1.2	1.3
	1.0	1.5	1.2	1.4
	1.0	...	1.3	1.2
	1.0	1.2	...	1.3
	1.1	1.3	1.4	1.3
	1.2	1.4	1.3	1.4
Total	8.5	8.9	9.0	10.3
Average	1.06	1.27	1.29	1.29
Average in inches	0.042	0.050	0.051	0.051

Per Cent of Carbon on First Cuts in Pins from Bottoms of Pots
Millimeters

Mixtures Nos.	1	2	3	4
	0.93	1.05	1.12	1.15
	0.955	1.09	1.25	1.15
	0.89	1.09	1.13	1.09
	0.97	1.09	1.02	1.16
Total	3.745	4.32	4.50	4.50
Average	0.936	1.08	1.12	1.12

Per Cent of Carbon; Second Cut; Same Pins
Millimeters

Mixtures Nos.	1	2	3	4
	0.82	0.96	0.97	0.91
	0.82	0.93	1.01	0.96
	0.83	0.98	0.97	1.01
	0.85	0.98	1.00	1.09
Total	3.32	3.85	3.95	3.97
Average	0.83	0.96	0.987	0.99

Per Cent of Carbon on Third Cut; Same Pins
Millimeters

Mixtures Nos.	1	2	3	4
	0.63	0.74	0.63	0.70
	0.63	0.79	0.71	0.72
	0.68	0.71	0.86	0.82
	0.75	0.75	0.91	0.86
Total	2.69	2.99	3.11	3.10
Average	0.672	0.747	0.777	0.775

Attention is invited to the fact that while mixture No. 4 is richer in both charcoal and chemical than mixture, No. 3 it did not produce any better results. Also that Nos. 3 and 4 are only slightly better than No. 2, but are much superior to No. 1. Yet there is no more difference between the chemical analysis of Nos. 1 and 2 than there is between Nos. 2 and 3 or 3 and 4.

In other words, this leads us to the conclusion that there is a certain amount of chemical that should be present in a carbonizing compound, but that more chemical can be added without materially changing the results. The minimum amount of chemical depends on which chemical is used and also on the other ingredients of the compound. As a general rule, it is dangerous to use a compound in which chemical content is near the minimum. It is the practice of the manufacturers to stay above the minimum.

After deciding upon what chemical to use and the proportions of all ingredients of the compound, the next big question to determine is how the chemical is to be made an integral part of the compound. Of course, powdered chemical could be mixed dry with granulated charcoal and coke, but when

such a mixture is shipped, there is a great danger that the chemical will become separated from the rest of the compound. Also there is a danger of loosing much of it in dust during handling. Certainly it is desirable to make the chemical an integral part of the compound. This is done in three ways: (1) By making pills; (2) by smelting the outside of the granules; and (3) by impregnating the chemical.

PILLS. The pill type compounds are made by grinding the various ingredients to dust. Then the different kinds of dust are thoroughly mixed together and with the help of some binder the whole mass is rolled into pills. These pills may or may not be coked. Whether the pills stand up on handling and during use or whether they break down into dust again, depends on the efficiency of the binder. The makers of pills claim that their product is more uniform.

SMEARED COMPOUNDS. Compounds of this type start with granulated charcoal or coke and smear the outsides of the granules with a mixture of the chemical and some binders. In this case the chemical is on the outside of the grains. How well it is held on depends upon the binder and the method of manufacture. The binder must be such that it will stand heating and still hold the chemical fast to the grains. Otherwise, after the first run there is simply a mechanical mixture of chemical in the form of dust and charcoal in considerably larger size grains. Again there would be the danger of separation and the formation of a nonuniform mixture.

SEMIPILLS. Between these two types there is the class of compounds which are made using the grains of charcoal and coke as the nuclei and smearing them with a mixture of chemical and charcoal dust together with a binder.

IMPREGNATED CHEMICAL COMPOUNDS. This type of compound is made by impregnating the chemical into the pores of the charcoal or the coke as the case may be. The makers of these compounds claim that their compounds are more durable because the chemical is on the inside instead of the outside of the grains.

* * * * * * * *

The above mentioned are the most common types of compounds on the market today and there are some very successful compounds in each class. It is also true that a novice at the game would be liable to make a very unsatisfactory compound no matter which method he chose.

It is worth mentioning that some compounds are made however, which, contain a great amount of oil. It is the claim that the hydrocarbons given off when these oils are heated, have a carbonizing action. Opponents of these materials, however, claim that the oil will all be vaporized and lost before the steel reaches the carbonizing temperature. However, if the pots are tightly sealed there may be considerable hydrocarbon vapor left in the pot after it reaches the carbonizing temperature.

This covers in a general way the principles involved in the manufacture of the modern commercial carbonizing compound. It is impossible, of course, to go into all the details with regard to formulas and the mechanical problems of manufacture, however, it is not as simple a problem as it might seem always to turn out a uniform compound on a large tonnage basis.

There are certain things that a carbonizing compound can do and there are some things that it cannot do. It adds carbon to the surface of the steel. The concentration of the carbon depends partly on the compound but this can be changed by subsequent heat treatments. The distribution of the carbon will be different in pieces that are slowly cooled as compared with those that

are quenched from the pot. Long continued heating at a temperature slightly lower than the carbonizing temperature will cause the case to sink in deeper and at the same time it will reduce the maximum carbon content at the outside. The compound may add sulphur, phosphorus or nitrogen to the steel and it is claimed that either of these will cause the case to be brittle.

The compound can not have any effect on the core of a case hardened piece. That is absurd. The properties of the core depend on the original steel and the heat treatment. Too much stress cannot be given the fact that the heat treatment following carbonizing has caused more trouble than all of the carbonizing compounds put together.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J. represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

ANDERSON, Richard, (M-5), 2822 Colfax Ave. N., Minneapolis, Minn.
BALCOM, Edgar P., (M-7), 58 May St., Worcester, Mass.
BENNETT, H. A., (M-6), Haughton Elevator & Machine Co., Toledo, O.
BERTRAM, W., (M-5), 2624 N. Jessup St., Philadelphia, Pa.
BIGELOW, R. E., (M-7), Geo. F. Blake Jr. & Co., Worcester, Mass.
BONTON, L., (M-5), 2520 S. 15th St., Philadelphia, Pa.
BROEMAN, Frank C., (M-4), 215 East Fourth St., Cincinnati, O.
BURCHFIELD, M. L., (M-3), 1380 West 73rd St., Cleveland, O.
BUSCH, Wilbur H., (M-4), Tate Jones & Co., P. O. Box 81, Dayton, O.
COOPER, Chas. H., (M-7), North East Electric Co., Rochester, N. Y.
COTE, J, E., (M-6), 81 Hill St., Shelton, Conn.
DALYRYMPLE, R. W., (M-7), Jones & Laughlin Steel Co., Pittsburgh, Pa.
DAMICO, A., (M-5), 1744 E. Passyunk Ave., Philadelphia, Pa.
FULLER, L. J., (M-7), Edgeworth, Sewickley, Pa.
GENERAL LIBRARY, (Sb-10), University of Michigan, Ann Arbor, Mich.
HAYNES, J. K., (M-7), 18 West St., Waterloo, N. Y.
HEATH, A. D., (S-7), General Alloys Co., Merchants Bank Bldg., Indianapolis
HOAGLAND, F. O., (M-7), Reed Prentice Co., Worcester, Mass.
KISSAM, W. H., (A-3), 1105 Chester Ave., Cleveland, O.
McBURNEY, J. W., (M-5), West Tech. High School, Cleveland, O.
MILLER, J. R., Jr., (M-7), Jones & Laughlin Steel Co., South Side Works, Pittsburgh, Pa.
MILNE, Alexander, (M-7), Jones & Laughlin Steel Co., Aliquippa Wks., Woodlawn, Pa.
MONTAGUE, W. T., (M-7), 13 Clearview Ave., Worcester, Mass.
MOULDER, W. J., (M-5), 1419 Porter St., Philadelphia, Pa.
Ind.
NELSON, George W., (M-5), 37 Sterling St., Worcester, Mass.
SMITH, J. R., (M-6), 13 Washington St., Armor Park, Charleston, W. Va.
SMITH, Wm. E., (S-7), Southington Hardware Co., Southington, Conn.
STANTON, Wm. F., (M-4), J. A. Fay & Egan Co., Front & John Sts., Cin-
TAKAO, Shigezo, (M-8), Takao Iron Works, Kobe, Japan.
cinnati, O.
WHITE, R. J., (M-7), 33 Alfred St., Springfield, Mass.

CHANGES OF ADDRESS

ALLISON, Fred G.—from 1817 State St. to 162 Meredith Ave., Milwaukee, Wis.
BIHLMAN, V. W.—from 32 Temple St., Springfield, Mass. to 361 N. Dawson St., Pittsburgh, Pa.
BUGIE, Chas. A.—from Heller Bros. Co., Newark, N. J. to 77 Sunnyside Terrace, E. Orange, N. J.
CARHART, W. H. C.—from Illinois Steel Co. to Interstate Iron & Steel Co., 104 S. Michigan Ave., Chicago, Ill.
CLARK, Edward L.—from 925 N. 27th St. to Commercial Truck Co., Hunting Park & Rising Sun Avenues, Philadelphia, Pa.

CROSSMAN, Leslie—from 15 Amherst St., Springfield, Mass., to 27 Richards St., Worcester, Mass.
DALRYMPLE, M. W.—from University Club, Bethlehem, Pa. to 3738 N. 7th St., Philadelphia, Pa.
DANSE, L. A.—from 882 Vermont Ave. to 2930 Pingree Ave., Detroit, Mich.
DERRON, D. L.—from Trading Engineers, Inc., Rua Sao Joao 309, Sao Paulo, Brazil, S. A. to 290 Cote des Neigas Rd., Montreal, Canada.
DIEDERICHE, Wm. J.—from 19 Howard St. to 278 Piedmont St., Waterbury, Conn.
EVANS, H. J.—from 201 Western Ave., Aspinwall, Pittsburgh, Pa. to Ridge & 14th Ave., New Kensington, Pa.
FELKER, A. W.—from Crucible Steel Co. of America, Cleveland O. to 1598 Elbur Ave., Lakewood, O.
FRETZ, W. S., from 1105 Lehigh St. to 1107 Butler Ave., Eaton, Pa.
GAFFNEY, Edwin P.—from Wheelock Lovejoy & Co., Chicago, Ill., to 140 Nassau St., New York City.
GRAVLIN, Albert M-10—from 236 W. Genesee St. to 810 Park Ave., Syracuse, N. Y.
[illegible] H.—from 461 South Ave., to 625 Reynolds St., Elmira, N. Y.
HOLLANDER, J. A.—from 2159 Lawn Ave., Norwood Sta., to 459 Lawn Ave., Cincinnati, O.
HORINE, Karl M-6—from Commonwealth Edison Co. to 28 N. Market St., Chicago, Ill.
LONGWELL, H. E. M-2—from Amer. Die & Tool Co., Reading, Pa. to 307 Wyman Park Drive, Baltimore, Md.
McQUIGG, C. E.—from Electro Metallurgical Co., Niagara Falls, N. Y. to Union Carbide & Carbon Research Lab., Inc., Thompson and Mauley Sts., Long Island City, N. Y.
MALACRIDA, J. T.—from 79 Elm St., West Haven, Conn. to 25 Lee St., Cambridge, Mass.
MARLOWE, J. S.—from 536 Bankers Trust Bldg., to No. 7 Mayflower Apts., Indianapolis, Ind.
MUENZEMAIER, Geo. A.—from Cincinnati Shaper Co., to National Lathe Co., 11-15 West Second St., Cincinnati, O.
PIERCE, Paul—from P. O. Box 709 to 2015 Bellefontaine Ave., Indianapolis, Ind.
PLATTS, J. C. M-11—from 9 Hartley St. H. O., Manchester, England, to 6A Fairfield Square, Droylsden, Manchester, England.
REDDERSON, E. W. M-4—from 6405 S. Wood St. to American Car & Foundry Co., 2503 South Wood St., Chicago, Ill.
REED, W. T.—from Geo. H. Smith Steel Castings Co., to 301 Ogelund Ave., Milwaukee, Wis.
SMITH, Paul—from 122 E. Ohio St., to Box 561, Indianapolis, Ind.
SQUIRES, John—from 4389 E. Chouteau Ave. St. Louis, Mo. to Old Colony Club, Detroit, Mich., care F. A. Curtiss.
SULLIVAN, Leo. D.—from 1558 Penobscot Bldg. to 4843 Bellevue Ave., Detroit, Mich.
SUTTON, Blair—from Crucible Steel Co. of America, to Sutton Abramson Eng. Co., 1901 Union Bank Bldg., Pittsburgh, Pa.
WILKINS, Chas. M-3—from 6436 Blackston Ave. to 4001 Drexel Blvd., Chicago.
WILLS, Wm. H.—from Braeburn Steel Co., Braeburn, Pa. to 437 South Ave. Wilkinsburgh, Pa.
WHONNHART, Lewis—from Sanderson Wks. Crucible Steel Co. to 621 S. Wilbur Ave., Syracuse, N. Y.
WOODWARD, A. F. M-4—from 621 G. St., S. W. Washington, D. C. to 827 Main St., Charleston, W. Va.
ZONKER, L. W.—from 822 Belmont Ave. to 1528 Thurston Ave., Racine, Wis.

MAIL RETURNED

AURELL, Carl, Billings & Spencer Co., Hartford, Conn.
CHENEY, Arthur M., Standard Steel & Bearing Co., Inc., 5001 Lancaster Ave., Philadelphia, Pa.
CONLON,, Wm. F., 321 Bryant Ave., Syracuse, N. Y.
GILMAN, R. L., 45 Read St., New Haven, Conn.
GRIFFITH, N. S., 4040 Olive St., St. Louis, Mo.
HANSON, H. E., 3616-64th Ave., West Allis, Wis.
HYNDS, J. J., Care Coronet Phosphate Co., Coronet, Florida.

KALENDER, Louis, 92 Florida St., Dorchester, Mass.
O'CONNOR, F. P., 199 Stryker Ave., Woodside, L. I., N. Y.
RABB, F. C., 324 Bordon Ave., Syraucse, N. Y.
ROSEN, Joe, The Linograph Co., Davenport, Ia.
SMITH, R. H., 171 High St., Boston, Mass.
WILLIAMS, R. W., Sheldon Axle & Spring Co., Wilkes Barre, Pa.

Commercial Items of Interest

Research facilities and the development activities of American industries are to be described in the forthcoming revision of Bulletin No. 2 of the National Research Council, "Research Laboratories in Industrial Establishments of the United States of America." Only 300 such laboratories were listed in the first edition but it is hoped that several hundred new names will appear in the revision and that a more nearly complete reference list will thus become available. The general demand for the first edition of the Bulletin shows the wide interest in this subject, and the importance of having every laboratory which devotes even a portion of its time to research properly listed. This Bulletin will be published at an early date.

The Council requests information from directors of research who have not already supplied it. The following data are wanted: Name and address of firm and address of laboratory; name of director of research; number on laboratory staff (classified as chemists, engineers, bacteriologists, etc.); approximate proportion of time spent on research; chief lines of research; unusual features of equipment; research laboratory space; date of organization of research laboratory and annual expenditure for research. Confidential information is not desired. This material should be furnished to the Research Information Service, National Research Council, 1701 Massachusetts avenue, Washington, without delay.

A contract for two sheet, two pair and six annealing furnaces was recently given to the Surface Combustion Co., Inc., 366 Gerard avenue, Bronx, New York, by the International Nickel Co., 67 Wall street, New York. The equipment will be installed in the latter company's new plant at Huntington, W. Va. Frank I. Ellis, 2126 Farmers Bank building, Pittsburgh, is the consulting engineer for the new plant, acting through W. L. Wotherspoon, chief engineer of the International Nickel Co.

The United States Civil Service Commission announces an open competitive examination for assistant metallurgical chemist on Aug. 17. Vacancies at the naval ordnance plant, South Charleston, W. Va., and vacancies in positions requiring similar qualifications will be filled from this examination. The duties of appointees will consist of analysis of steel, iron, alloys and other metallurgical materials and will require ability to make quick test analysis of steel for the following elements: Carbon, silicon, manganese, sulphur, phosphorus, nickel and chromium. Full

TRANSACTIONS

of the

American Society for Steel Treating

Vol. 1 Cleveland, September, 1921 No. 12

THE COMING CONVENTION AND EXHIBITION

ON SEPT. 19 the American Society for Steel Treating will convene in Indianapolis for its Third Annual Convention. The meeting will mark the first anniversary of the amalgamation into one great society of two societies devoted to the heat treatment of steel, the formal proceeding of which took place in Philadelphia on Sept. 14, 1920. From every standpoint, the uniting of forces has been an advantage and the Society has been able to exert an influence greater than would have been possible by two organizations having the same purpose. Executive reports to be submitted at the business session of the Convention will testify as to the truth of this statement.

During the year just passed the Society has had a well rounded growth. Today all classes of membership aggregate 3200 members, a substantial increase over one year ago. At the time of amalgamation the society consisted of 27 local chapters; at the present time it can boast of 31, a gain of four chapters. This gain is significant other than in point of numbers for the new chapters installed during the year have expanded the territorial area in which the Society exerts an influence. By reason of large active memberships, embracing representatives from practically all plants in which heat treated products are made, local chapters have been able to secure able speakers and high caliber technical papers. The most important of these have been published in TRANSACTIONS from time to time. Chapters of the Society will be found to rank top notch among other technical organizations in all engineering and industrial centers.

Thus it is with a satisfaction of work well done and a desire to accomplish more that the Society meets in its coming convention. In spite of the present business depression which is affecting all industry, present indications point to a highly successful convention. Plans have been well made both by the National Headquarters and the Indianapolis Chapter for the entertainment of members and guests while remaining in Indianapolis. The Papers Committee has secured a most complete list of technical papers as is attested to by the program printed elsewhere in this issue. For the first time simultaneous sessions are to be held, an arrangement which will permit the presentation of a greater number of papers than heretofore and will enable members to attend the sessions in which they are most interested. It is hoped that this plan of conducting meetings will encourage discussion, which is a prime purpose of every convention.

As in the past an exhibition will be held in connection with the convention. For this purpose the Manufacturers Building at the State Fair Grounds has been secured. It has sufficient floor space for booths and is

so provided with gas and power facilities that exhibitors will display their equipment in working order. Although business conditions are not such as to warrant more than conservative exhibits, the Society has been fortunate in securing a large list of exhibitors, who will have on display the latest and most efficient products and equipment used in heat treating. That these exhibitors who make the Convention of the Society possible by their patronage will be at considerable expense in presenting their products goes without saying. Thus it is hoped that members and guests will attend the exhibition frequently and by inspecting the various exhibits will show the greatest appreciation.

HOTEL RESERVATIONS ARE HEAVY

HOTELS in Indianapolis already are reporting heavy registration for the week of Sept. 19. Thus it is important that members and guests who are planning to be present should write immediately to the various hotels in order to secure their reservations.

Indianapolis has promised to provide our guests with excellent accommodations as far as hotels are concerned, and through the efforts of J. E. Burns Jr., chairman of the Hotel Committee, a list of hotels is given below.

All persons in attendance at Indianapolis will make their own reservations direct with the managers of the hotels, and it is advisable that the members take this precaution. When making reservations give date of arrival, kind of room desired, and price you wish to pay, and what is most important, request the hotel manager to answer your letter repeating the reservation. Then present the letter when you register.

This precaution taken now may avoid serious difficulty at the time of the Convention.

It is recommended that reservations be made immediately.

The list of hotels follows:

Hotels	Capacity	Rates
Brevort Hotel	94 Rooms	$1.25 to $3.00 per day
New Colonial Hotel	92 "	$2.00 to $4.00 " "
New Denison Hotel	175 "	$1.25 to $2.00 " "
Edward Hotel	150 "	$1.25 to $4.00 " "
Grand Hotel	76 "	$1.50 to $3.00 " "
Hotel Lincoln	100 "	$2.00 up " "
Lorraine Hotel	90 "	$1.00 to $4.50 " "
New Morton Hotel	65 "	$1.50 to $5.00 " "
Great Eastern Hotel	126 "	$1.25 to $3.00 " "
Stubbins Hotel	75 "	$1.00 to $4.50 " "
Hotel Severin	400 "	$2.50 to $8.00 " "
Hotel Washington	300 "	$2.50 to $4.00 " "
Hotel Williams	92 "	$1.75 up " "
Terminal Hotel	45 "	$1.50 up " "
Ohio Hotel	40 "	$1.50 up " "
Claypool Hotel	700 "	$2.50 up " "
Frohman Hotel	80 "	not over $3.50 " "
Haugh Hotel	60 "	" " " " "
Linden Hotel	250 "	" " " " "
Majestic Hotel	59 "	" " " " "
Roosevelt Hotel	187 "	" " " " "
Royal Hotel	85 "	" " " " "

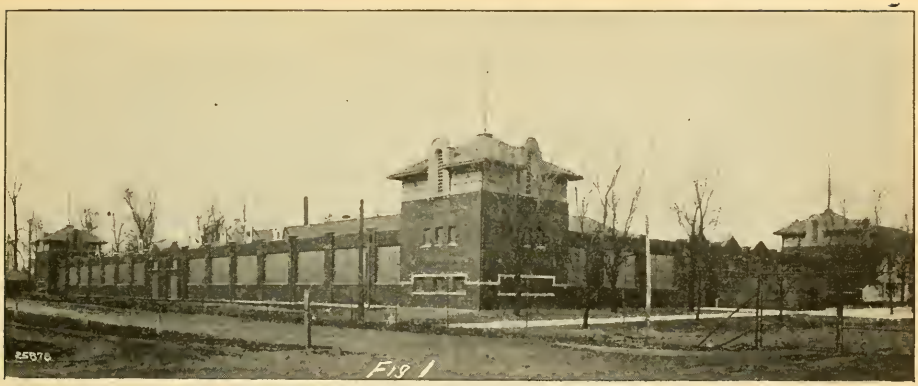

FIG. 1—MANUFACTURES BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE THIRD ANNUAL EXHIBITION OF THE AMERICAN SOCIETY FOR STEEL TREATING WILL BE HELD, SEPT. 19-24

MATCH RACE FOR THE INDIANAPOLIS CONVENTION

GEORGE DESAUTELS, chairman of the Entertainment Committee for the Convention and Exhibition of the American Steel Treating Society to be held at Indianapolis, Sept. 19 to 24, has issued announcement of a match race between Frontenac and Duesenberg automobiles.

This 50-mile match race will be staged on the Speedway, Wednesday morning, Sept. 21 at 10.00 a. m. This is the first time in the history of the Speedway that consent has been given for staging a race of any kind on this track other than the Annual Race on Decoration Day.

Three or four Frontenac cars and three Duesenberg machines will be entered.

These two manufacturers of racing cars are located in Indianapolis and are great rivals, thus it will be a good race inasmuch as both firms are particularly anxious to secure the valuable trophy which will be presented to the winner.

In addition to the match race Mr. Duesenberg has agreed to stage an exhibition with his special car which has made a record of 156 miles per hour. It is also possible that Jimmie Murphy and his car in which he won the Grand Prix in France will also be in Indianapolis, and enter this race which is being arranged for the benefit of the visitors and delegates to the steel treating Convention. .

While the race probably will be the largest event and probably of greatest interest to the visitors, nevertheless, Mr. Desautels has arranged for golf tournaments, tennis tournaments, and ball games between the eastern and western delegates. Dances, smokers, vaudeville, and a continual round of enjoyment are promised for the visitors. Indianapolis has always been the most hospitable city and the steel treaters are looking forward to having the largest Convention, and the most enjoyable occasion in their history.

SPORT IN INDIANAPOLIS

GEORGE DESAUTELS, chairman of the Entertainment Committee; is planning to have an inter-city tennis tournament, and also an inter-city golf tournament. Any exhibitor, member or guest from the various

cities may enter these tournaments. Trophies will be awarded the winning tennis team, and to the best golfer. The course at Highland Golf and Country Club has been secured for the golf tournament. This course represents the sportiest and best in the United States, and it will be a treat to every golfer to try out the excellent course.

Not only will there be prizes for the individuals and teams turning in the lowest score, but there will also be prizes for the dubs. So do not permit the fact that you are no low medal artist prevent you from bringing your golf sticks along and enjoying the game. If you're going to bring your golf sticks and tennis rackets along, communicate with George Desautels, Imperial Drop Forge Co., Indianapolis.

THE LADIES

BRING them with you to Indianapolis. Then check them with the Ladies Entertainment and Recepton Committee. They will be well taken care of.

At the previous Conventions of the Society many of the visitors succeeded in persuading "Friend Wife" to go with them, and the ladies were so well taken care of, that it is now impossible for these visitors to attend the Convention unless they bring their wives.

The Ladies Entertainment Committee has arranged a most tempting program and will keep the ladies pleasantly and advantageously busy during the entire week.

The Ladies' Headquarters will be on the mezzanine floor of the Claypool Hotel, and will be open every day of the Convention with a secretary in charge.

FIG. 2—INTERIOR OF MANUFACTURES BUILDING, SHOWING A PART OF THE 76,000 SQUARE FEET OF FLOOR SPACE TO BE USED BY THE EXHIBITORS

PROGRAM FOR THE CONVENTION

AT THE time of going to press, it is impossible to list various papers which will be read upon certain days of the Convention; however, programs will be distributed at the Convention and will give complete information. The general plan for the presentation of papers has been laid out subject to slight changes, and will be about as follows:

Monday, Sept. 19—Opening Session, 2 P. M., Women's Building, State Fair Grounds, Indianapolis, Ind.

Chairman, W. R. Chapin

Address of Welcome .....
W. R. Chapin, Chairman Executive Committee, Indianapolis Chapter
Welcome to Indianapolis .....City Official
Response .....A. E. White, National President
Report of Tellers of Election.....R. T. Bayless, Chairman
Report of Secretary.....W. H. Eisenman, National Secretary
Report of Treasurer .....W. S. Bidle, National Treasurer
President's Address .....A. E. White, National President
Announcements.

Tuesday, Sept. 20

10 A. M.—Papers on Carburizing.
2 P. M.—Papers on Tool Steel.
6 P. M.—Smoker and Entertainment.

Wednesday, Sept. 21

10 A. M.—Motor Speedway.
50-Mile Match Race between Duesenberg and Frontenac Motor Cars.
2 P. M.—Room A.—Papers on Heat Treating Equipment—Room B—Papers on Alloy Steel
8 P. M.—Dance and Entertainment

Thursday, Sept. 22

10 A. M.—Room A—Program in charge of the Army and Navy—Room B—Papers on Alloy Steel
2 P. M.—Room A—Papers on Metallographic Research—Room B—Papers on Heat Treating Equipment
6 P. M.—Annual Banquet. Speakers of National Prominence

Friday, Sept. 23

10 A. M.—Research Session in charge of Dr. Harrison E. Howe, Chairman of the National Research Council, Washington, D. C.
2 P. M.—Room A—Papers on Heat Treating Problems—Room B—Papers on Shop Management

Special attention is called to the fact that owing to the large number of excellent and interesting papers, simultaneous sessions will be held on three days of the Convention so that visitors may have the opportunity of attending the sessions which are of the greatest interest.

Army and Navy Session

The Army and Navy program on Thursday morning will be especially interesting and the following general program will be presented.

The Chief of the Navy will detail an officer to present a paper on "Laying of the North Sea Barage."

General Amos A. Fries, chief of Chemical Warfare Service will have a paper presented on some subject of interest to the members.

General C. C. Williams, chief of the Ordnance Department has

asked F. C. Langenberg, metallurgist of the Watertown Arsenal to present a paper on the heat treatment at the Arsenal.

Major L. W. McIntosh, assistant to the Chief of Engineering Division, Air Service, War Department, will have a paper presented on "Heat Treating Problems in Aeronautics."

Research Session

Dr. Harrison E. Howe, chairman of the National Research Council will preside at the Research Session on Friday morning. Dr. Howe has consented to secure the speakers for that session, in which the general plan for research in heat treatment will be presented and discussed.

PAPERS TO BE PRESENTED AT THE CONVENTION

INVESTIGATION and progress in heat treating is being made every day and steel treaters should keep abreast of the times. It is but necessary to read the comprehensive list of papers given below in order to be satisfied that the topics mentioned and the men pre-

FIG. 3—WOMAN'S BUILDING, STATE FAIR GROUNDS, INDIANAPOLIS, WHERE SESSIONS OF THIRD ANNUAL CONVENTION OF THE SOCIETY WILL BE HELD

senting them will make it worth while to go hundreds of miles to hear them.

After reading this list over carefully, consult with the other executives of your firm, and undoubtedly they will agree with you that it is absolutely necessary to send representatives to the convention if you are to continue to maintain the high standard of your products.

Manufacturers realize as never before that the materials they produce are only as good as their heat treatment. It is an interesting fact that the most successful firms are those concentrating and devoting a great amount of thought and capital to the development of their heat treating plants.

Now is a time when money must be saved, expenses must be reduced, and while it may be felt that business conditions would not justify a visit to the Convention, it is only necessary to obtain but one

important idea which you may be applied to conditions in your own plant in order to be more than fully repaid for the entire expense of the trip.

A few days spent in Indianapolis will increase efficiency and save money in plant operation.

Following is a list of papers which will be presented at the various sessions of the Convention:

TOOL STEEL

C. M. BROWN, V. P. Colonial Steel Co., Pittsburgh, Pa. Paper: *"Tool Steel "Specifications."*

W. G. CALKINS, Metallurgist, Detroit Twist Drill Co., Detroit, Mich Paper: *"Notes on Forged High Speed Milling Cutters."*

A. H. d'ARCAMBAL, Metallurgist, Pratt & Whitney Co., Hartford, Conn. Paper: *"Physical Tests on High Speed Steel."*

A. W. F. GREEN, Metallurgist, John Illingworth Steel Co., Philadelphia, Pa. Paper: *"Providing Properly Rolled Tool Steel for the Steel Treater."*

L. K. MARSHALL, Metallurgist, North East Electric Co., Rochester, N. Y. Paper: *"Tool Steel Manipulation."*

M. H. MEDEWEFF, Met. 5014 Weseley Ave. Howard Park, Baltimore, Md. Paper: *"Heat Treatment and Uses of High-Speed Steel."*

T. HOLLAND NELSON, Steel Works Mgr., H. Disston & Sons, Philadelphia, Pa. Paper: *"A Comparison of American and English Methods of Producing High Grade Crucible Steels."*

L. R. SEIDEL, Managing Director, New York Testing Laboratories, N. Y. City. Paper: *"Tool Steel."*

A. S. TOWNSEND, Ch. Chemist, Cleveland Twist Drill Co., Cleveland. Paper: *"The Effect of Tungsten Content on the Specific Gravity of High Speed Steel."*

METALLOGRAPHIC RESEARCH

R. L. DOWDELL, Instructor of Metallography, University of Minnesota, St. Paul, Minn. Paper: *"Reclaiming High Carbon Gears."*

J. P. GILL and L. D. BOWMAN, Metallurgist and Asst. Metallurgist, Vanadium Alloy Steel Co., Latrobe, Pa. Paper: *"Metallography of High Speed Steel."*

N. B. HOFFMAN, Metallurgist, Colonial Steel Co., Pittsburgh, Pa. Paper: *"Ghost Lines and Grain Elongation in Hot Rolled and Cold Drawn Iron Wire."*

F. C. LAU, Consulting Engr., 1437 W. Jackson Blvd., Chicago, Ill. Paper: *"The Effect of Phosphorus in Tool Steel."*

HEAT TREATMENT OF STEEL

D. N. A. BLACET, Met. Central Steel Co. Paper: *"Modern Methods of Heat Treating."*

I. H. COWDREY, Professor of Mechanical Engineering, Massachusetts Inst. Tech., Cambridge, Mass. Paper: *"The Efficiency of Annealing Overstrained Steel."*

L. S. COPE, Consulting Metallurgist, 920 Mary St., Ann Arbor, Mich. Paper: *"Coarse Grained Forgings; Their Detection and Correction."*

E. J. JANITZKY, Metallurgist, Illinois Steel Co., South Chicago, Ill. Paper: *"A Contribution to the Problem of the Influence of Mass on Heat Treatment."*

J. F. KELLER, Dept. of Forging & Heat Treating, Lewis Institute, Chicago, Ill. Paper: *"The Whys of Warping."*

C. B. LANGSTROTH, Met. A. O. Smith, Milwaukee, Wis. Paper: *"Heat Treatment of Steel."*

H. E. HAYWARD, Met. Link Belt Co., Indianapolis, Ind. Paper: *"Malleable Iron."*

S. L. HOYT & G. H. BIERMAN, Met. Engrs., National Lamp Works, Nela Park, Cleveland, O. Paper: *"On the Theory of Hardening Steel."*

T. D. LYNCH, & W. J. MERTEN, Met. Engrs. Material & Process Eng. Dept., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"Tests Showing the Effect of High Temperature on Malleable Iron."*

W. J. MERTEN, Met. Engr., Westinghouse Electric & Mfg. Co. Paper: *"A Coiling and Heat Treating Plant for Helical Springs."*

W. P. PRIESTLEY, Supt. of Hot Metal Div. U. S. N. O. P., Charleston, W. Va. Paper: *"Fracture Test on Steel to Determine its Quality."*

W. R. WARD, Metallurgist Engineer, Lyells, Va. Paper: *"Miscellaneous Heat Treating."*

W. H. WHITE, Supt. of Melting Shops, U. S. N. O. P., Charleston, W. Va. Paper: *"Heat Treatment of Steel Castings."*

J. A. GANN, Metallurgist, Dow Chemical Co., Midland, Mich. Paper: *"Dowmetal and Its Application."*

CARBURIZING

C. M. CAMPBELL, Supt. Pioneer Alloy Products Co., Cleveland, O. Paper: *"Do Alloy Carbonizing Boxes Pay?"*

H. H. HARRIS, Pres., General Alloys Co., Chicago, Ill. Paper: *"Design of Heat Treating Containers."*

V. E. HILLMAN, Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"The Efficiency of Various Mixtures for Cynaide Hardening and The Role of Nitrogen in the Process."*

W. I. McINERNY, Foreman Heat Treat. Armor Plate U. S. N. O. P., Charleston, W. Va. Paper: *"Carburizing Heavy Sections."*

H. SCHAGRIN, Ch. Chemist, U. S. N. O. P., Charleston, W. Va. Paper: *"Carburization with Wood Charcoal."*

T. G. SELLECK, V. P. GURNEY & SELLECK, 513 Peoples Gas Bldg., Chicago, Ill. Paper: *"Carburizing."*

P. W. & E. B. SHIMER, Metallurgical Engrs., Easton, Pa. Paper: *"Cyanide in Liquid Case Hardening."*

S. C. SPALDING, Metallurgist, Halcomb Steel Company Syracuse, N. Y. Paper: *"Comparison of the Rate of Penetration of Carbon Into Various Commercial Steels Used for Case Carburizing."*

MANAGEMENT

A. E. BELLIS, Pres. Bellis Heat Treating Co., New Haven, Conn. Paper: *"Shop Management."*

A. A. BLUE, Metallurgist, Duff Mfg. Co., Pittsburgh, Pa. Paper: *"A Successful Bonus System Applied to Heat Treating."*

J. WALTER BRESSLER, Philadelphia, Pa. Paper: *"System of Records for Metallurgical Departments."*

F. C. LANGENBURG, Metallurgist, Watertown Arsenal, Watertown, Mass. Paper: *(Title to be supplied later.)*

E. W. PIERCE, Metallurgist, Maxwell Motor Car Co., New Castle, Ind. Paper: *"Buying Steel on Closer Carbon Limits."*

C. F. SMART, Asst. Ch. Metallurgist. Ingalls-Shepard Div. Wyman-Gordon Co., Harvey, Ill. Paper: *"Steel Is Steel."*

W. P. WOODSIDE, Superintendent of Materials, Studebaker Corp., Detroit, Mich. Paper: *"Organizing Research To Pay Dividends."*

W. P. WOOD, Professor of Chem. Engineering, University of Michigan, Ann Arbor, Mich. Paper: *"A University Course in Metallurgical Engineering."*

H. F. WOOD and F. G. MILLARD, Ch. Metallurgist, and Supt. of Finishing Dept. Ingalls-Shepard Division, Wyman-Gordon Co., Harvey Ill. Paper: *"Production Efficiency in the Heat Treatment of Drop Forgings."*

M. H. MEDWEDEEF, Met. 5041 Weseley Ave., Howard Park, Baltimore, Md. Paper: *"Metallurgy in the Modern Shop."*

ALLOY STEEL

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper: *"Tensile Properties of Some Structural Steels at High Temperatures."*

M. A. GROSSMAN, Metallurgist, Electric Alloy Steel Co., Youngstown, O. Paper: *"The Toughness of Alloy Steels as Affected by Their Heat Treatment."*

C. M. JOHNSON, Director of Research, Park Works Crucible Steel Co. of America, Pittsburgh, Pa. Paper: *Some Alloy Steels of High Elastic Limit, Their Microstructure and Heat Treatment."*

G. C. McCORMICK, Asst. Metallurgist, Crompton & Knowles Loom Works, Worcester, Mass. Paper: *"A Discussion of Uranium and Allied Elements."*

H. STYRI, Chief of S. K. F. Research Laboratories, Philadelphia, Pa. Paper: *"Heat Treatment of Chrome Steel for Ball Bearings."*

J. S. VANNICK, Metallurgist, Research Laboratory, Department of Agriculture, Washington, D. C. Paper: *"Mechanical Properties of Chrome Vanadium Steels."*

PROPERTIES OF CARBON AND ALLOY STEELS

R. M. BIRD, Metallurgist, Bethlehem Steel Co., Bethlehem, Pa. Paper: *"Standardization of Methods Leading to Comparative Properties of Alloy Steels."*

A. M. COX, Asst. Metallurgist, R. D. Nuttall Co., Pittsburgh, Pa. Paper: *"Abrasive Qualities of Plain and Alloy Steel."*

H. J. FRENCH and W. G. JOHNSON, Physicist and Asst. Physicist, Bureau of Standards, Washington, D. C. Paper: *"Effect of Heat Treatment on Mechanical Properties of One Per Cent Carbon Steel."*

H. A. HOLZ, Pres. Holz & Co., New York. Paper: *"Recent Researches on the Elastic Limit."*

L. W. WILD, Pres., Wild Barfield Co., London, England. Paper: *"Influence of Heat Treatment on the Magnetic Properties of Steel."*

H. J. FRENCH, Physicist, Bureau of Standards, Washington, D. C. Paper: *"Effect of Heat Treatment on Mechanical Properties of Carbon Molybdenum and Chrome Molybdenum Steels."*

HEAT TREATMENT EQUIPMENT

W. H. BRISTOL, Pres., Bristol Co., Waterbury, Conn. Paper: *"Automatic Compensation for Variation of Cold Ends of Thermo-Electric Pyrometers."*

E. D. CAMPBELL, Professor of Chemistry, University of Michigan, Ann Arbor, Mich. Paper: *"Some Brinell Hardness Measurements on Small Specimens."*

GEORGE KELLER, Sales Mgr. Brown Instrument Co., Philadelphia, Pa. Paper: *(Title to be supplied later).*

R. W. NEWCOMB, Mgr. Charles Engelhard, Inc., New York City. Paper: *"A New Type Automatic Temperature Regulator. Its Application to Heat Treating Furnaces."*

T. Y. OLSEN, V. P. Tinius Olsen Testing Machine Co., Philadelphia, Pa. Paper: *"Determinator of Stiffness of Wire on Sheet Metal."*

S. P. ROCKWELL, Metallurgist, Whitney Mfg. Co., Hartford, Conn. Paper: *"Testing of Metals for Hardness."*

C. UPTHEGROVE, Professor of Chemical Engr., University of Michigan, Ann Arbor, Mich. Paper: *"Note on the Small Brinell Machine."*

FURNACES

T. F. BAILEY, V. P. Electric Furnace Co., Alliance, O. Paper: *"Electric Furnaces for Heat Treating With Automatic Control."*

G. R. BROPHY, Metallurgical Engr., Indus. Furnace Dept. General Electric Co., Schenectady, N. Y. Paper: *"Calite; A New Heat Resisting Alloy."*

E. F. DAVIS, Sales Mgr. Celite Products Co., New York Paper: *"Construction of Furnace Doors, Lining and Bases."*

F. J. EVANS, Sales Mgr. Eng. Surface Combustion Co., Springfield, Mass. Paper: *"High Pressure Gas and Its Application to Industrial Furnaces."*

J. T. GOWER, Armstrong Cork & Insulation Co., Pittsburgh, Pa. Paper: *"Reducing Conduction and Radiation Heat Loss."*

C. L. IPSEN, Designing Engr., General Electric Co., Schenectady, N. Y. Paper: *"The Electric Furnace as it Affects Overall Costs of Heat Treated Parts."*

P. J. LAFORE, Industrial Eng., Boston Consolidated Gas Co., Boston, Mass. Paper: *"The Use of Gas Fired Furnaces for Heat Treating."*

G. M. LITTLE, Res. Engr. Div., Westinghouse Electric & Mfg. Co., Pittsburgh, Pa. Paper: *"An Electrically Heated Forging and Heat Treating Furnace."*

W. E. McGAHEY, Foreman, Heat Treating Large Guns, U. S. N. O. P., Charleston, W. Va. Paper: *"Heat Treatment of Large Forgings by Oil, Gas and Electricity."*

A. F. MITCHELL, Supt. Heat Treating U. S. N. O. P., Charleston, W. Va. Paper: *"A Comparison of Conditions Entering Into the Operation of Oil and Natural Gas Fired Furnaces."*

J. WEAVER SMITH, Inds. Engr., Citizens Gas Co., Indianapolis, Ind. Paper: *"Gas Accessories for the Heat Treating Room."*

R. E. TALLEY, Ch. Engr., Geo. J. Hagan Co., Pittsburgh, Pa. Paper: *"Operating Data on Electric Furnaces."*

MISCELLANEOUS TOPICS

A. E. WHITE, University of Michigan; and J. S. Vannick, Bureau of Standards. Paper: *"Note on Occurrence of Oxides and Nitrides in Boiler Tube Steel."*

F. H. HELRIGEL, Metallurgist, Motor Products Co., Detroit, Mich. Paper: *"The Heat Treatment of Copper and Brass."*

EXHIBITORS AND PRODUCTS THEY WILL EXHIBIT

THE exhibition this year will be one of the most interesting and important the Society has ever held. There will be more exhibits in operation than ever before. Over 70 firms, as listed below, producing the highest class of products will be there to meet you and greet you, and not only to explain their products but to answer any questions you may have, and help you solve the difficulties in which you may be entangled.

A glance at the list of firms below will show that they represent the leaders, and they are anxious that you should examine their products. There is nothing that could be of greater value to you than to come to the Convention and Exhibition to examine at first hand the very latest in new equipment and products which should be used.

The list of exhibitors given below is not complete due to the fact that it was necessary to close the forms preparatory to going to press. The program distributed at the Convention will contain complete information.

Following is the partial list of exhibitors and their products:

Alcorn, Blockhouse Co., Philadelphia, Pa.

Armstrong Cork & Insulation Co., Pittsburgh, Pa., will exhibit:
Nonpareil insulating brick for the retention of heat in furnaces, ovens, boiler settings and other high temperature equipment.
Nonpareil high pressure covering and blocks for steam lines, feed water heaters, enameling, and japanning ovens, etc.
Nonpareil cork covering for insulation of drinking water systems in mills and factories.
Nonpareil corkboard for the insulation of cold storage and constant temperature rooms.
In Charge of Booth: J. T. Gower.

E. C. Atkins Mfg. Co., Indianapolis, Ind.

Atlas Crucible Steel Co., Dunkirk, N. Y.

Bausch & Lomb Optical Co., Rochester, N. Y., will exhibit:
Metallographic equipment and metallurgical microscopes, including two new metallographic equipments and a new form of illuminant.
In Charge of Booth: W. L. Patterson and L. I. Nixon.

Bell & Gossett Co., Chicago, Ill., will exhibit:
"Caseite"—case hardening compound.
"Bathite"—preheating bath.
Pots and Boxes.
"Cleancoat"—lead bath covering.
Selective hardening material.
In charge of Booth: E. J. Gossett.

Bethlehem Steel Co., Bethlehem, Pa., will exhibit:
One large transparency consisting of 32 photographs with appropriate colors showing representative views of all operations at a steel plant from raw materials to the finished steel product.
A new truck wheel, showing the various operations from the I-beam section to the finished wheel.
Two boards of bolts and nuts.
A number of different castings made with additions of Mayari iron, consisting of motor castings, such as pistons, cylinder heads, motorcycle cylinders; grinding plates, etc.
Several very interesting tool steel boards.
A board of drop forgings.
In Charge of Booth: W. R. Shimer, W. H. Laury, W. C. Cutler and John Moran.

Bristol Company, Waterbury, Conn.

The Brown Instrument Co., Philadelphia, Pa., will exhibit:

Apparatus to demonstrate what the research departments of instrument manufacturers are doing today, along the lines of developing newer and more accurate instruments. The Brown Instrument Co. plans to exhibit a number of striking samples of radical changes and improvements in instrument design and construction.

At this booth will be displayed a potentiometer, so compact that it can be carried under the arm, and yet has a scale of 96 inches long.

Automatic control showing what has been accomplished during the last year.

The heating cycle controller.

New cold junction compensated pyrometer, together with the complete line of high resistance indicating and recording pyrometers of single continuous and multiple types; indicating and recording thermometers; indicating and recording pressure gages; tachometers; and all types of instruments for temperature measuring and recording.

In Charge of Booth: G. W. Keller, C. C. McDermott, D. J. Jones, R. W. Mayer, E. R. Robinson, and S. C. Ketterer.

Bureau of Standards, Washington, D. C., will exhibit:

General equipment available for metallurgical research and testing of metals. Copies of publications considered of interest to the society will be available for examination, and typical examples of the Bureau's metallurgical work will be featured.

The exhibit as a whole will give a general idea of the scope of this work and co-operation with the metal industries.

In Charge of Booth: G. K. Burgess, H. J. French, and Miss D. E. Kingsbury.

Calorizing Co. of Pittsburgh, Pittsburgh, Pa., will exhibit:

New and used specimens of Calorizing and Calite, with some working tests of the latter material.

In Charge of Booth: B. L. Jarrett, A. V. Farr, E. L. Malone, A. A. Becker, F. D. Rice, G. H. Howe and G. R. Brophy.

Case Hardening Service Co., 2281 Scranton Road, Cleveland, O., will exhibit:

A case hardening compound, samples of Bohnite, also samples of work it has produced. These samples include gears, cam shafts, etc., which have been cut to show the cross section and polished and etched to show the depth of case.

Two new devices for testing the hardness of metals which will be shown for the first time in the United States. They are both manufactured by the Rudge-Whitworth, Ltd., Birmingham, Eng.

The first, called the Auto-Punch, is a portable Brinell machine weighing only a few pounds and can be carried easily to any part of the shop or plant. The impressions made are somewhat smaller than made with the standard Brinell Machine. The instrument is manufactured for shop and production use and is so simple that any workman can operate it and yet it is accurate enough for laboratory purposes if needed.

The second instrument, known as the Quadrant Sclerometer, is used for testing the hardness of wrist pins, steering bolts, etc., and is made from two ordinary files hinged together at one end. One of these is placed in a horizontal position by the means of leveling screws. The hardness of the piece is then ascertained according to the friction generated.

In Charge of Booth: William H. Bell and C. E. Lovejoy.

Celite Products Co., New York, will exhibit:

Heat treating materials in various forms showing representative applications.

Sil-O-Cel heat insulating products, brick and powder.

Sil-O-Cel C-3 cement for forming furnace and oven doors.

Exhibit will include model furnace in operation to illustrate graphically the insulating value of Sil-O-Cel.

In Charge of Booth: E. F. Davis, H. N. Haberstroh and R. V. Massman.

Central Steel Co., Massillon, O., will exhibit:

Various steel products.

Machinability of oil hardening steels.

In Charge of Booth: F. J. Griffith, D. N. A. Blacet, L. B. Baker, C. P. Richter, and C. Beach.

Colonial Steel Co., Pittsburgh, Pa., will exhibit:
High and low carbon steel, high speed steel, annealed steel, overheated steel, burned steel, etc., to be viewed with microscope.
An auto-propector showing views pertaining to the manufacture of crucible tool steel.
In Charge of Booth: Charles M. Brown, T. H. Nimick, J. E. Barry, and N. B. Hoffman.

Crucible Steel Co. of America, Pittsburgh, Pa., will exhibit:
Complete line of steels and products manufactured from same.
In Charge of Booth: C. W. Mayer, J. W. Taylor, F. J. White, E. R. Mills, H. L. Raynor, R. Slaughter and E. E. Sharp.

Deeds Commercial Laboratories, Indianapolis, Ind., will exhibit:
Carburizing compound, demonstrating methods of use as well as the principle of quenching.
In Charge of Booth: W. C. Horner.

Deeds & Chapin Co., Indianapolis, Ind.

Driver-Harris Co., Harrison, N. J., will exhibit:
Representative Nichrome castings.
In Charge of Booth: H. D. McKinney, W. E. Blythe, C. B. Calloman, H. D. Hardegan, and H. D. Tietz.

Eaton Electric Furnace Co., Taunton, Mass.

Electric Alloy Steel Co., Youngstown, O.

Electrical Refractories Co., East Palestine, O., will exhibit:
Electrical refractories for use in resistance-type electric heating devices, including electric ranges, steel treating furnaces, enameling ovens, immersion heaters, and laboratory equipment.
In Charge of Booth: E. C. Owen.

Electric Steel Co. of Indiana, Indianapolis, Ind.

Charles Engelhard, Inc., New York, will exhibit:
Thermoelectric pyrometers.
Thermocouple parts, such as protecting tubes.
Completely assembled thermocouples.
Indicating instruments—several types.
Recording instruments—single and multiple-record.
Automatic temperature regulator.
Electric furnaces.
Impervite refractories.
In Charge of Booth: E. S. Newcomb and G. V. Nightingale.

J. B. Ford Co., Wyandotte, Mich.

William Ganschow Co., Chicago, Ill., will exhibit:
Heat treated gears of all kinds.
Spur gear speed transformer.
Bakelite and rawhide noiseless gears.
In Charge of Booth: A. F. Boissoneau.

General Alloys Co., Chicago, Ill., will exhibit:
Q—Alloys—supreme heat resisting alloys.
Will announce a new alloy at the show.
In Charge of Booth: H. H. Harris, A. D. Heath, A. L. Grinnell, P. F. McGovern, and O. A. Parine.

General Electric Co., Schenectady, N. Y.

George J. Hagan Co., Pittsburgh, Pa., will exhibit:
One 42-kilowatt electric furnace in operation. This furnace will be automatically controlled, and is representative of a complete line of electric furnaces which the George J. Hagan Co., carries in stock and manufactures in its factory at Orrville, O. This particular equipment is suitable for hardening, annealing, and carburizing steel; annealing nonferrous metals; and enameling.
One combination oil and gas-fired heating furnace in operation, with gas fuel and with automatic temperature control; also samples of oil burners for indus-

trial furnace work and steam generation, and oil burners in combination with gas fuels of various sorts for industrial furnace work.
In Charge of Booth: W. C. Buell Jr., and R. E. Talley.

Halcomb Steel Co., Syracuse, N. Y., will exhibit:
Inserted tooth and disk saws, dreadnought high speed steel.
Cold-drawn high speed steel and its products.
Punches, dies, gages, Ketos nonshrinking steel.
Automobile parts of electric alloy steels.
Bolt and nut making, Halco and Pyro hot-work steels.
Magnet steel products, stainless steel and its uses.
Wortle drawing dies, ball wire, and the making of balls, hot and cold.
In Charge of Booth: A. T. Galbraith, M. P. Spencer, J. S. Marlowe and H. J. Stagg.

Heppenstall Forge & Knife Co., Pittsburgh Pa., will exhibit:
Piston Rod—showing physical properties.
Die block—giving record run while in service.
Frames containing drop forgings—showing the type of block from which they were made and average yield.
Photographs of the plant.
Shear knife—showing fracture and micrographic structure.
In Charge of Booth: J. A. Succop.

Hoskins Mfg. Co., Detroit, Mich., will exhibit:
An electric heat treating furnace, the temperature of which is automatically controlled, and which employs a new type of heating element.
Pyrometers, indicating and recording.
Nickel-chromium heat-resistant castings.
In Charge of Booth: W. D. Little, C. S. Kinneson, and C. F. Busse.

Imperial Drop Forging Co., Indianapolis, Ind.

Indianapolis Drop Forge Co., Indianapolis, Ind., will exhibit:
Drop forged dies and tools and drop forgings.
In Charge of Booth: Ferdinand Barnickol, J. C. Beyer, L. M. Fehrenbach, and Ferdinand Barnickol Jr.

Indianapolis Light & Heat Co., Indianapolis, Ind.

The Industrial Press, New York, will exhibit:
"Machinery" and its different publications.
In Charge of Booth: J. N. Wheeler, V. S. Wunder, E. K. Hammond, and H. L. Brown.

The Iron Age Publishing Co., New York, will exhibit:
The Iron Age and publications.
In Charge of Booth: F. J. Frank, C. S. Baur, F. W. Schultz, D. C. Warren, W. B. Robinson, J. Lundberg, F. S. Wayne, Emerson Findley, Don G. Heinly, B. L. Herman, E. Sinnock, C. L. Rice, A. L. Marsh, H. A. Douglass, H. E. Barr, and W. C. Sweetser.

Kinney Mfg. Co., Chicago, Ill., will exhibit:
Small motor driven positive pressure rotating plunger pump, in operation.
In Charge of Booth: A. J. Munday.

Leeds & Northrup Co., Philadelphia, Pa., will exhibit:
"Hump" method electric furnaces in operation. (Bring small tools for hardening.)
Indicating and recording pyrometers and optical pyrometer in operation.
In Charge of Booth: G. W. Tall, Jr., A. E. Tarr, Jordan Korp, Henry Brewer, Oscar Brewer, and C. A. Martin.

Marschke Mfg. Co., Indianapolis, Ind., will exhibit:
Electrical motor-driven bench and floor-type grinders and buffers. These machines are made in the plant complete, including motors and safety devices.
In Charge of Booth: F. W. Marschke, W. A. Marschke and H. W. Marschke.

Midvale Steel & Ordnance Co.—Cambria Steel Co., Pittsburgh, Pa.

Oakley Chemical Co., New York, will exhibit:
Oakite cleaning methods and materials for removing quenching and tempering oils, thus affecting economy in labor and money. Working conditions are better, disagreeable odors and health undermining fumes are eliminated, and

methods of handling so improved that substantial savings are possible.
Oakite service men will be present in booth 60 to offer suggestions on individual problems of removing quenching and tempering oils, or other industrial cleaning problems.
In Charge of Booth: Maxwell Lakeman and C. A. Ormsby.

The Penton Publishing Co., Cleveland, O., will exhibit:
The Iron Trade Review and publications.
In Charge of Booth: F. V. Cole, John A. Penton, A. O. Backert, J. D. Pease, C. J. Stark, H. O. Taylor, L. C. Pelott, A. L. Klingeman, G. H. Manlove, E. L. Shaner, D. M. Avey, A. M. Pulaski, H. E. Diller, E. F. Ross, A. J. Hain and D. O. Taber.

Quigley Furnace Specialties Co., Inc., New York, will exhibit:
Hytempite: Demonstration of this high temperature cement for banding fire brick, blocks, tiles, and granular refractories.
Insulbrix: Refractory insulating brick for conservation and maintenance of uniform temperatures.
Carbosand: Highly refractory fire sand for furnace linings and floors, patches and repairs to linings, and for making special shapes and tile.
In Charge of Booth: W. H. Gaylord and F. W. Reisman.

W. S. Rockwell Co., New York City.

P. H. & F. M. Roots Co., Connersville, Ind., will exhibit:
One No. ½ Roots horizontal low-pressure blower, motor drive. This blower will be used for furnishing air for one half of the live exhibits at the Convention.
One No. 4 Roots Acme gas pump, arranged for drive by constant speed motor and equipped with diaphragm operated by pass valve This gas pump is of the type used for boosting the gas pressure to hardening furnaces and other industrial appliances.
The Original Roots blower. This machine is the first one manufactured by Mr. Roots in 1859.
One No. 3 Roots Acme blower arranged for single-pulley drive. This machine will not be in operation and will be for inspection only.
One No. 3½ Roots Acme blower, arranged for tight and loose-pulley drive. This machine will also not be in operation and will be for inspection only.
One No. 1 Roots Acme hand blower. This machine is of the type ordinarily furnished for use with portable forges and blacksmith fires. It will be on exhibition for examination and operation by visitors.
One No. 1 Roots horizontal low-pressure blower, pulley-drive. The case and headplates of this machine will be cut away so as to show the rotating parts. It will also be arranged to rotate slowly showing the relation and operation of the internal mechanism.

Simonds Mfg. Co., Lockport, N. Y., will exhibit:
High speed tool steel.
Carbon tool steel.
Alloy steels.
Sheets and bars.
In Charge of Booth: H. D. Need and G. R. Bird.

Smith Gas Engineering Co., Dayton, O., will exhibit:
Small model clean gas producer of sufficient capacity to operate furnaces.
In Charge of Booth: Wm. P. Duff, E. A. Adams, and R. M. Chatterton.

Spencer Turbine Co., Hartford, Conn., will exhibit:
Spencer multiturbo compressor for supplying air for oil and gas burning furnaces.
In Charge of Booth: S. E. Phillips and H. M. Grossman.

Stromberg Electric Co., Chicago, Ill., will exhibit:
Process timing and signalling instruments for controlling the time element and preventing the process from running too short or too long a time.
Sromberg No. 35 job time recorders, printing exact time of start and completion of work on any job or operation.
Stromberg in-and-out employees' recorders for payroll and time records.
Stromberg electrical time stamps for stamping exact time on all kinds of papers passing through various departments.
In Charge of Booth: Wm. P. Martin Jr.

Surface Combustion Co., New York City.

Tate-Jones & Co., Inc., Pittsburgh, Pa.

Taylor Instrument Companies, Rochester, N. Y.

Vanadium-Alloys Steel Co., Latrobe, Pa., will exhibit:
High-speed, carbon and alloy tool steels, and tools and products made from the same.
In Charge of Booth: J. P. Gill, W. R. Mau, A. G. Henry and R. D. Guisewite.

Westinghouse Electric & Mfg. Co., Pittsburgh, Pa.

Wilson-Maeulen Co., New York, will exhibit:
Rockwell hardness tester in three sizes. Also pyrometers, tapaloy, monopivot indicators and pyods.
In Charge of Booth: C. H. Wilson, Harry Goldsen and S. C. Horn.

Witherow Steel Co., Pittsburgh, Pa.

THE METALLURGY OF HIGH SPEED STEEL

By D. M. Giltinan

DEVELOPMENT of high speed steel as distinguished from carbon tool steel, has been a matter of the last 50 years. The development of the present day cutting alloys in this short space of time, as compared with the hundreds of years previous in which there was no development, calls for some explanation. This explanation lies in the fact that the manufacturing industries of the civilized world have, during the same period, demanded a means for securing increased production without the increase in cost which would accompany additional buildings and equipment. The alternative was to speed up each individual machine, and in attempting to do so, it at once became apparent that the tool steel then in use would not meet the requirements of increased speed. These requirements were:

1. The tool must possess initial hardness greater than the material cut, and also must be sufficiently hard to resist wear.

A paper presented before the Charleston Chapter. The author, D. M. Giltinan, is associated with the micro laboratory, Bureau of Research, United States Naval Ordnance Plant, Charleston, W. Va.

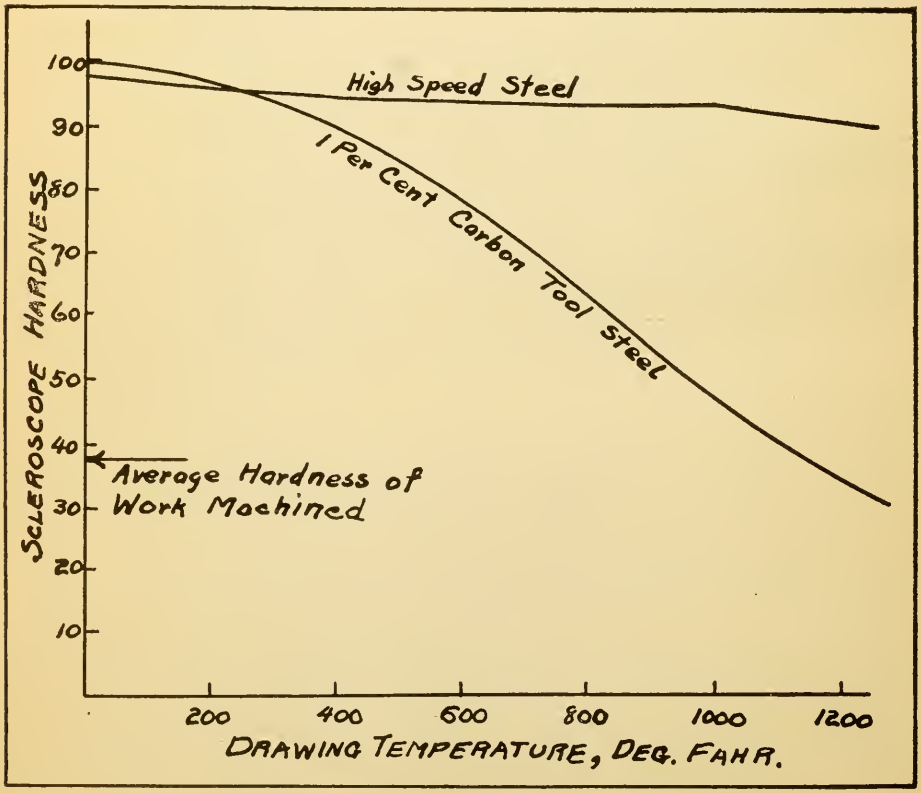

FIG. 1—EFFECT OF HEAT ON HARDENED STEEL

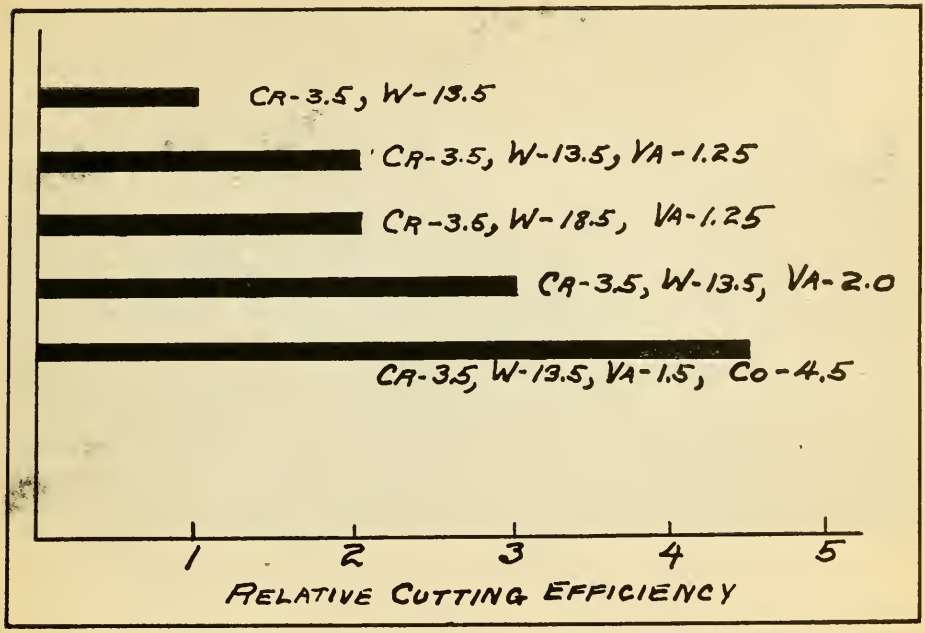

FIG. 2—COMPARISON OF VARIOUS HIGH SPEED STEELS

2. The tool must not soften when subjected to the heat developed through friction, due to increased relative speed of the tool and the work.

Tool steel, in the generally accepted sense of the word, is an iron-carbon alloy containing from 0.6 to 2.0 per cent carbon with an average of approximately 1.0 per cent carbon. The carbon exists as iron carbide, or cementite, Fe_3C, which is extremely hard, and above 1350 degrees Fahr., the stable condition of the alloy is a solid solution of Fe_3C in the iron or ferrite. Below 1350 degrees Fahr., the Fe_3C separates out of the solid solution and the stable condition is a mixture of Fe and Fe_3C, which is comparatively soft, due to the cementite being isolated in globules or plates in the soft ground mass of ferrite. If the solid solution is cooled rapidly the carbide is held in solution, resulting in uniform hardness throughout; but the alloy is in a meta-stable condition and will revert readily to the stable upon application of heat. This softening commences at about 300 degrees Fahr., and at 1300 degrees Fahr. or dull red, the steel has become very soft. This is illustrated graphically in Fig. 1.

Present high speed steels, on the other hand, when properly hardened are initially hard, and moreover there is only a small decrease in hardness when heated to a dull red; that is, high speed tools are as hard when operating at speeds where friction is sufficient to make tool red hot as are carbon steels, when operating under conditions of very light cut and feed and low speed.

The development of the modern high speed steel as shown by Table I, started in about 1866, when Robert Mushet of Sheffield, discovered the value of manganese as an alloying element of bessemer steel, giving added ease of fabrication. In the source of further ex-

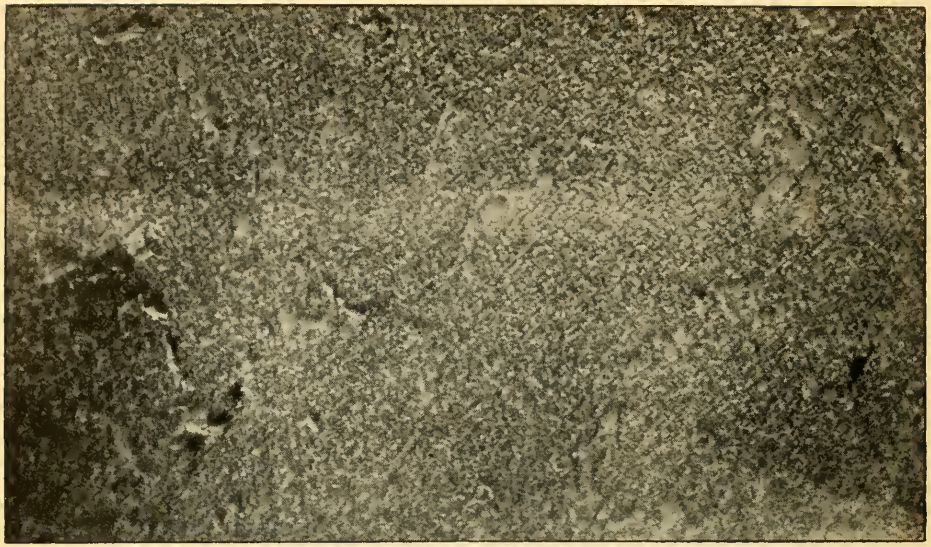

FIG. 3—PHOTOMICROGRAPH OF HIGH SPEED STEEL IN THE ANNEALED STATE X 1000

perimental work with manganese on tool steels, he noted that one particular composition possessed the property of hardening when cooled in air. This was distinctly out of accord with the knowledge of steel hardening at that time, and careful analysis developed the fact that there was considerable tungsten present in addition to the manganese, as shown by No. 1, Table I. The combination of tungsten and manganese in conjunction with high carbon resulted in a lowering to below room temperature of the point where the carbide separated out of the solid solution, giving the property of "air hardening", a term which was at once applied as a trade name to this particular tool steel. Some few years later, Henry Gladwyn, an associate of Mushet's, noted that when this steel was cooled from a yellow heat, 1700 1800 degrees Fahr., in the air blast even better results were obtained. This steel found some application in machine shops working on very hard material, but it was not generally used to speed up production, due probably to the great difficulty encountered in fabrication and dressing of tools.

It was not until about 1890 that there was any further improvement in tool steels and the next step was taken by America. Fredrick Taylor, founder of the Taylor System of Scientific Management, was at that time chief engineer at the works of the Midvale Steel Co. in Philadelphia, and was an enthusiast on the subject of increasing the production of the various machine tools. The difficulties of handling Mushet tool steel led to the discovery that by replacing the manganese with chromium and cutting the carbon content in half and increasing the tungsten content slightly, a steel was produced which had the air-hardening properties of Mushet's, was a superior cutting alloy and was readily forged to shape.

When Mr. Taylor, in 1896, went with the reorganized Bethlehem Steel Co., he continued his experiments in search of a steel with which he could increase production still more, and during the period between

1898 and 1900 he discovered the great increase in cutting speed made possible by heating the tools practically to melting point when hardening. This was a revolutionary step, as it had always been known that heating a carbon steel any higher than necessary to produce uniform solution of the carbide resulted in a coarsening of the crystallization and accompanying brittleness when hardening. In fact, a carbon tool steel heated as high as 2300 degrees Fahr. would be absolutely ruined. Further work at Bethlehem showed the advantage of higher chromium content, and between 1902 and 1906 there was in Europe and America a movement which resulted in the adoption of carbon content now generally in use 0.60 to 0.80 per cent and increasing the amounts of chrome and tungsten up to the maximum of 7 per cent chromium and 24 per cent tungsten. It was found, however, that the maximum efficiency was obtained with a chromium content of 3 to 4 per cent and 18 per cent tungsten. Molybdenum was also tried in place of tungsten, or to replace it partially, but it was found that while molybdenum produced an excellent high speed steel, it was rather uncertain and caused seams and hardening cracks so that its use was discontinued.

About the same time vanadium was added in this country, and, while it was found that it improved the cutting capacity, it was thought erroneously as it later turned out, that the increase obtained did not compensate for the additional cost entailed. In 1908-1909, Europe and America brought out simultaneously a high tungsten steel containing

Table I

Development of Cutting Alloys

High Speed Steels

No.	Year	Composition Per Cent												
		C	Mn	Si	Ni	Cr	W	Va.	Co	Mo.	Ur	Al.	Zr	Fe.
1	1868-70	2.5	2.0	.70	....	..	6.0	...	...	...	...	...	...	...
2	1890-94	1.4	.20	.25	....	1.7	8.0	...	...	...	...	...	...	...
3	1900	1.5	.30	.15	....	3.8	8.0	...	...	...	...	...	...	...
4	1902	1.4	.20	.25	....	2.5	10.0	...	...	...	...	...	...	...
5	1903	.70	.30	.30	....	3.0	13.0	...	...	...	...	...	...	...
6	1903	.70	.20	.10	....	3.0	18.0	...	...	...	...	...	...	...
7	1905	.70	.20	.20	....	7.0	24.0	...	...	...	...	...	...	...
8	1906	.35	.13	.08	....	6.0	9.0	...	...	8.0	...	...	...	...
9	1906	.70	.05	.05	....	6.0	18.0	.50	...	...	...	...	...	...
10	1908	.60	.20	.20	....	4.0	18.0	1.0	...	...	...	...	...	...
11	1910	.60	.20	.20	....	4.0	14.0	1.0	...	...	...	...	...	...
12	1913-14	.70	.20	.20	....	4.0	14.0	2.0	...	...	...	...	...	...
13	1914	.70	.20	.20	....	3.5	18.0	1.5	4.5	...	...	...	...	...
14	1915	.65	.30	.20	....	3.5	14.0	1.25	4.5	...	...	...	...	...
15	1916	.75	.30	.20	....	4.0	14.0	1.75	...	...	0.50	...	...	...
						Semi-High Speed Steels.								
16	....	1.00	.20	.20										
						Carbon Tool Steel.								
17	1868-90	1.40	.55	.25	....	...	2.0	...	...	...	...	...	...	...
18	"	1.20	.30	.20	....	...	7.0	...	...	...	...	...	...	...
19	"	.70	.10	.30	....	1.5	...	...	...	...	...	...	...	...
20	1905-10	2.5	.30	.20	....	14.0	...	...	...	...	...	...	...	...
21	1915	1.4	.30	.20	....	19.0	...	...	...	...	...	...	...	...
22	1917	1.6	.30	.80	....	12.0	...	...	3.5	...	...	...	...	...
						Nonferrous Alloys.								
23	1914	1.5	...	...	....	30.0	6.0	...	50.0	...	...	...	...	12.0
24	1916	1.5	...	6.0	65.0	15.0	...	...	...	...	...	6.0	...	6.0
25	1917	0.3	...	6.0	80.0	...	...	...	...	...	...	4.0	4.0	5.0

approximately 1 per cent vanadium which met with immediate success, and since that time vanadium has been an essential component of practically all high speed steels. Its action has never been understood fully, and there have been few attempts to explain its effect, which is to increase the life of the tool when working at high temperatures.

Shortly after this it was found that in steels containing vanadium, the tungsten could be lowered to 13 or 14 per cent with an increase in cutting capacity, which was more marked if vanadium content was increased to as high as 2 per cent. In the last few years cobalt has been added with considerable success; first in Europe and later in this country. Like every other addition which has increased the cutting powers of high speed steel, it has made the material more susceptible to abuse and has not come into very general use.

From its position in the periodic table, that is, in the Cr, Mo, W group, it seems reasonable to assume that uranium would be a valuable high speed element. Recent experiments have shown, however, that in the amounts in which it has been possible to alloy it with high speed steel, its effect is nil. It is very difficult to get it into solution in the steel due to large losses caused by oxidation or insolubility. Tantalum has also been added experimentally, but it tends to prevent air-hardening and has shown no beneficial effect. Relative cutting efficiencies are shown in Fig. 2.

Developing with the high speed steels there have grown up several alloy steels, which while not possessing high speed characteristics, have

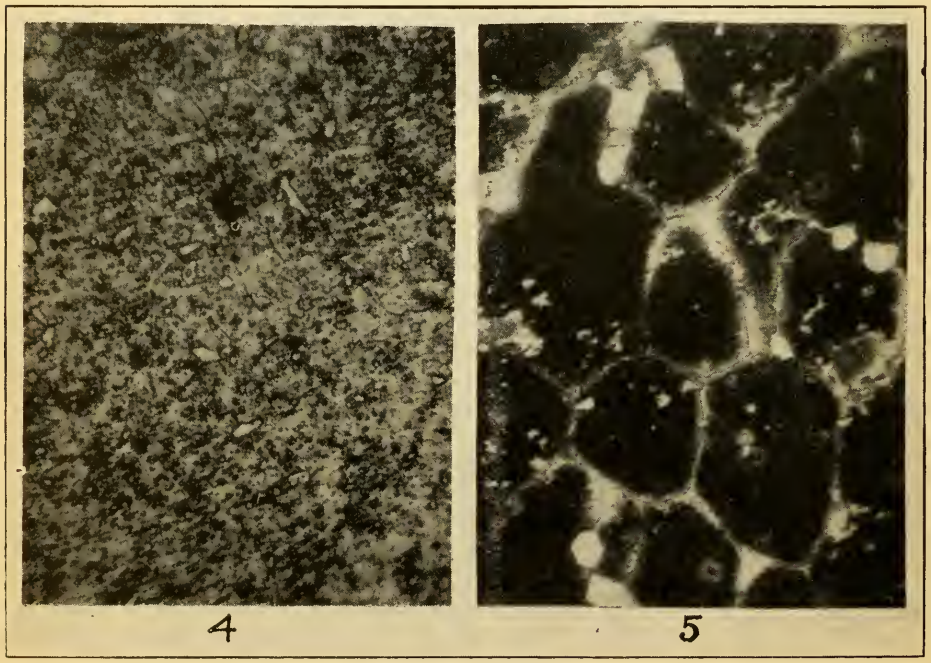

FIG. 4—STEEL HEATED TO NORMAL HARDENING TEMPERATURE. X 600. SHOWS LINES OF AUSTENITIC GRAINS, VERY LARGE. CARBIDE PARTICLES NOT IN SOLUTION. FIG. 5—CUTTER BURNED BY SEVERE OVERHEATING X 600. SHOWS PARTIAL FORMATION OF INTERGRANULAR EUTECTIC

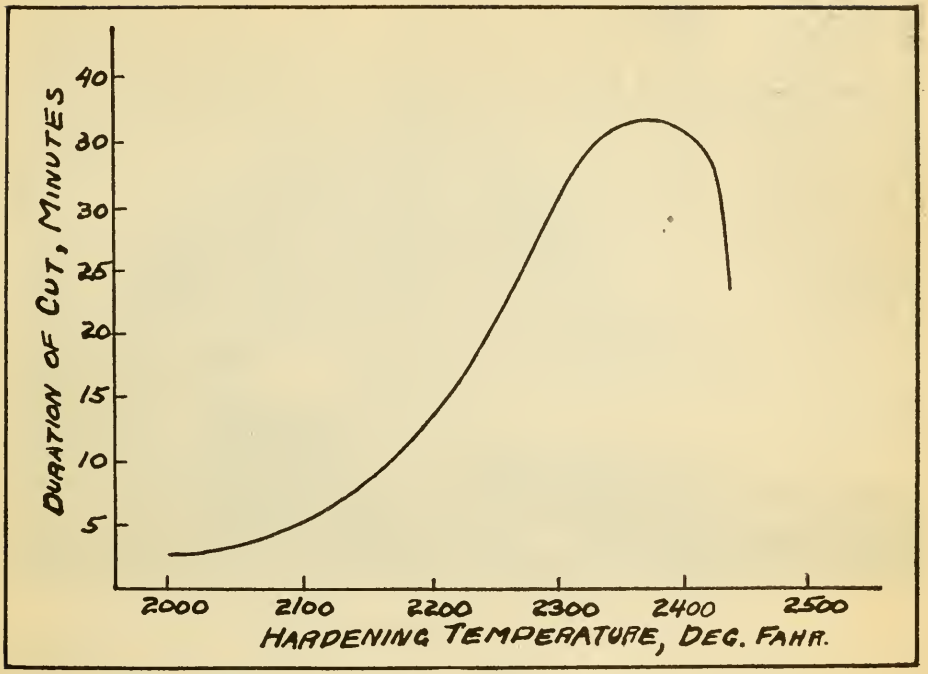

FIG. 6—EFFECT OF HARDENING TEMPERATURE ON CUTTING CAPACITY OF HIGH SPEED STEEL

found a considerable field in some classes of work where the alloying elements have produced tools possessing keen cutting edges suitable for finishing work. In the period between 1880 and 1890 tungsten was added to tool steel of 1.00 to 2.5 per cent carbon, which upon quenching from the ordinary temperatures for tool steel, 1400-1500 degrees Fahr. gave a tool possessing a durable cutting edge on light work. Later chromium was added to straight carbon tool steel, but only with the idea in mind of increasing the resistance to wear, not that of increasing speed.

In the period between 1905 and 1910, there was developed in England and France, a steel of high carbon content, 2.50 per cent, and high chrome 14 per cent. This steel possessed a very fine grain, cutting capacity far superior to carbon tool steel, though inferior to high speed steel, and moreover, the special advantage of not deforming on hardening. The hardening temperature was only 1600 to 1700 degrees Fahr. as opposed to 2200 to 2300 degrees Fahr. necessary for high speed steel. It, however, like the original Mushet steel, was difficult to forge, and on the account of the large loss in manufacture, it has been followed to a certain extent in this country by a steel of 1.5 per cent carbon and 17 to 20 per cent chromium, which possesses the same nondeforming qualities, but is more readily fabricated.

Within the last half year, in view of the scarcity of tungsten, there has been brought out in England a high speed steel "substitute", for which rather extravagant claims have been made. It is very similar to the nondeforming steels mentioned previously, with the addition of cobalt and while cobalt improves the cutting capacity over the same

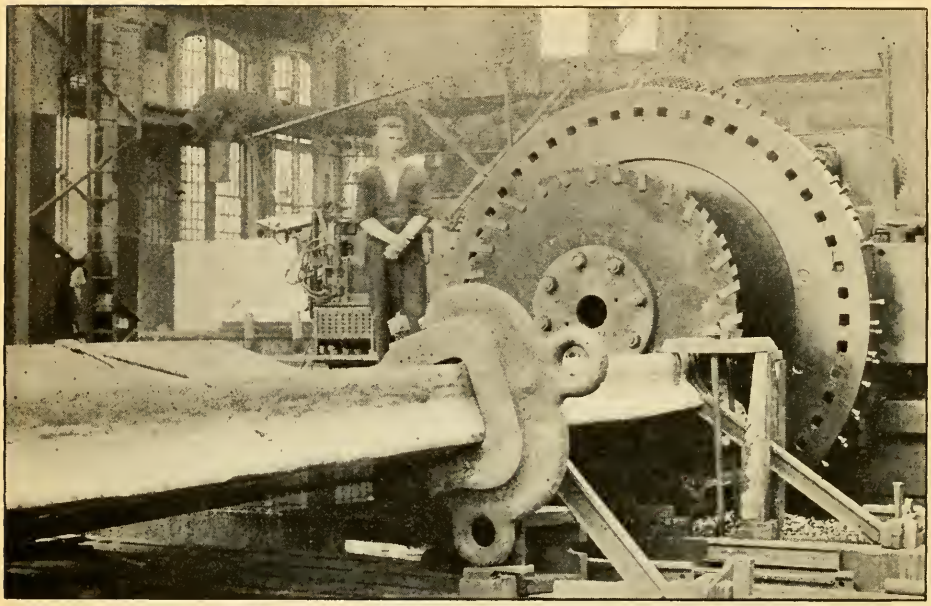

FIG. 7—COLD SAW MADE OF HIGH SPEED STEEL

steel without cobalt, it by no means is capable of working at high speed and heavy cutting conditions.

Some interesting nonferrous alloys have been brought out within the last five years, but they do not take the place of high speed steels as yet. This steel, essentially a chrome-cobalt alloy, was put on the market in 1913 by Elwood Haynes of automobile fame. It is a very hard and fine grained alloy, and although quite brittle, it is capable of extreme speed when in the hands of a competent mechanic. It may be heated to a bright red or orange, 1700 degrees Fahr., without any softening effect. It is rather high priced, due to the large percentage of cobalt.

In 1916, an English concern bought out a cutting alloy, which was largely nickel and chromium, with about 6 per cent each of aluminum and silicon. It is believed that these two elements form an intermetallic compound of extreme hardness, which is chiefly responsible for the success of the alloy, as a simple nickel-chome combination of approximately the same composition does not answer the purpose as a cutting tool.

An interesting alloy, very similar in some ways to the one just mentioned is one developed in the United States within the last year. It consists of approximately 80 per cent nickel, 4 to 6 per cent of aluminum and silicon and about 4 per cent of zirconium, a metal which is new when used in this connection. This alloy possesses a quality similar to the steel developed by Mr. Haynes though somewhat inferior; but like all the nonferrous alloys which have yet been developed, it does not possess the requisite toughness to withstand the heavy blows which high speed steel tools contend with in heavy roughing cuts or "Hogging" as it is called in the shops.

The manufacture of high speed steel involves no different processes

than those by which all high grade cutting steels have made for the past hundred years, although of course, like all other manufacturing processes, certain refinements and minor improvements are made from time to time. At the present time in this country, most high speed steel is made by the crucible process, although the electric furnace method is gaining in favor, due to the ability of the latter to refine low grade material. In the crucible process a predetermined amount of high speed steel scrap, low carbon bar iron, ferrochrome, ferrovanadium and either tungsten powder or ferrotungsten are packed in crucibles and sealed with sand or clay. Each pot holds about 100 pounds, and about 30-35 pots are put in the furnace at one time, melted and thoroughly mixed after melting by pouring into the ladle, from which the ingots are cast. As soon as the metal in the ingots is solidified the mold is stripped and ingots are cooled very slowly, either in ashes or in a soaking pit. Extreme precautions must be taken, as high speed is very sensitive to rapid temperature changes and would crack if allowed to cool suddenly.

The ingots are then annealed to remove any strains set upon casting, and are carefully heated for fabrication. The ingots may be either rolled or hammered to bars after which the latter are reannealed and are ready for shipment. It is customary to ship bars annealed in order that any machine work may be done on them.

Microscopic examination at high magnifications, 500-1000 diameters, shows that high speed steel in the annealed state Fig. 3, consists of a matrix of what is probably the solid solution of iron and tungsten, which

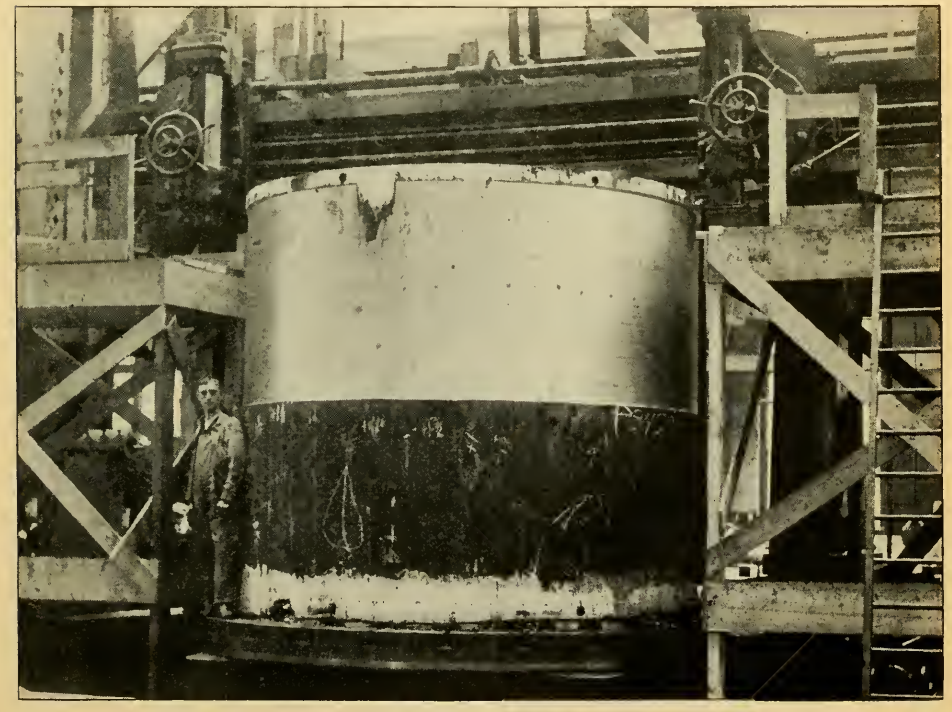

FIG. 8—VERTICAL BORING MILL USING HIGH SPEED STEEL TOOLS

is studded with innumerable globules or "ponds" which have been identified as carbides or tungstides of iron and chromium or a combination of both.

Upon quenching this steel from ordinary temperatures, that is, 1400-1700 degrees Fahr., there is practically no change in structure and there is only partial hardening, showing that solution of carbide is necessary for hardness. Tools hardened from these temperatures do not realize the possibilities in any way. It is only by heating to at least 2250 or 2300 degrees Fahr., that the carbide shown in Figs. 4 and 5, may be brought into solution and it is then only that the full possibilities as a cutting tool are obtained. The effect of hardening temperature on cutting capacity is shown in Fig. 6. There is, of course, an extreme in high temperature, and if this is passed, more injury than good results. The steel is partially melted and an intergranular eutectic, which is extremely brittle, is formed upon cooling. This eutectic structure cannot be broken up by annealing and is always a source of trouble.

There have been several theories advanced for the selfhardening properties and so-called red hardness of high speed steels, none of which are entirely satisfactory, but all of them have their adherents. To show the trend of opinion the following theories of self hardening and red hardness are enumerated:

1. *Bohler*—"Wolgram & Rapidstahl"—Wien, 1904.

Austentite pearlite transformation is suppressed with increase in chromium and tungsten and furthermore the higher the initial temperature the greater the suppression of this point resulting in eventual lowering below the room temperature.

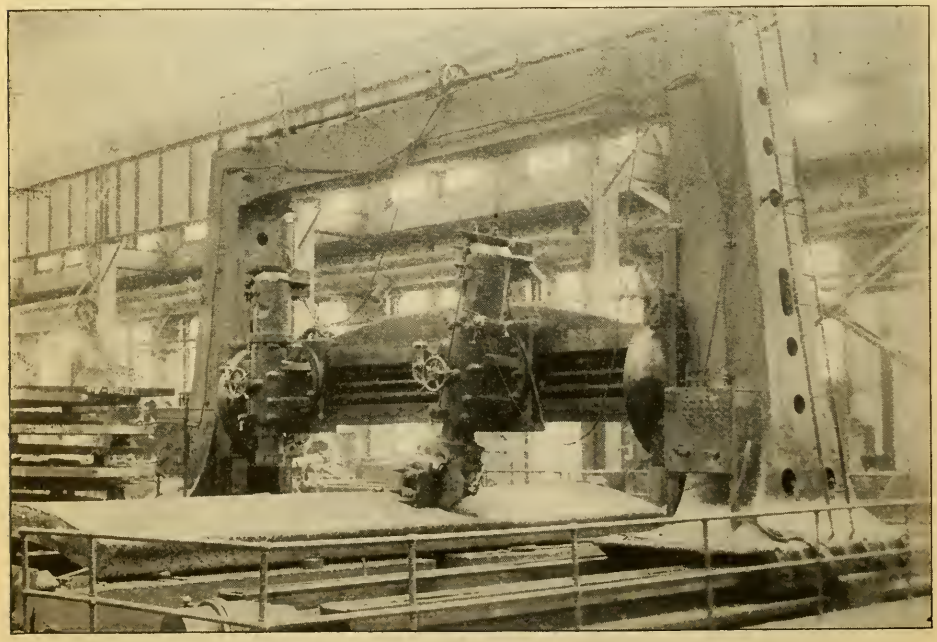

FIG. 9—ARMOR PLANER UTILIZING HIGH SPEED STEEL TOOL

2. *Osmond*—Paris. Chromium and tungsten lower the carbon content of pearlite, making steel of 0.60 to 0.80 per cent really a hypereutectoid steel, and furthermore prevent separation of cementite, so that the rate of cooling has little effect. An increase in the carbon content results in the lowering of transformations, so that by varying the amount of carbide in solution, that is, by heating to higher temperatures, these transformation points are lowered to room temperature with an austenitic structure resulting. No particular explanation of red hardness is given.

3. *Carpenter.* Tungsten and chromium promote retention of the austenitic structure due to lowering of the transformation points cooling. Upon drawing, austenite is converted to martensite with the result that at a temperature of 1000-1200 degrees Fahr., high speed steel is as hard as carbon steel at ordinary temperatures.

4. *Edwards*—Manchester.

A—Formation of tungsten carbide at 2200 degrees Fahr., and solution of this carbide at 2350-2400 degrees Fahr.

B—Assumes that chromium combines with carbon and goes into solution at once on passing Ac range, but that tungsten does not go into solution until temperature of 2300-2400 degrees Fahr., is reached. The chromium is responsible for air hardening properties of the steel. Edwards accounts for red hardness as follows: Upon drawing a straight chromium alloy, there is a gradual decrease in hardness, while on drawing a straight tungsten alloy there is an increase up to 1000-1100 degrees Fahr., and then a decrease, therefore complete solution of tungsten is necessary to produce secondary hardening.

5. A theory which seems plausible would be a combination of

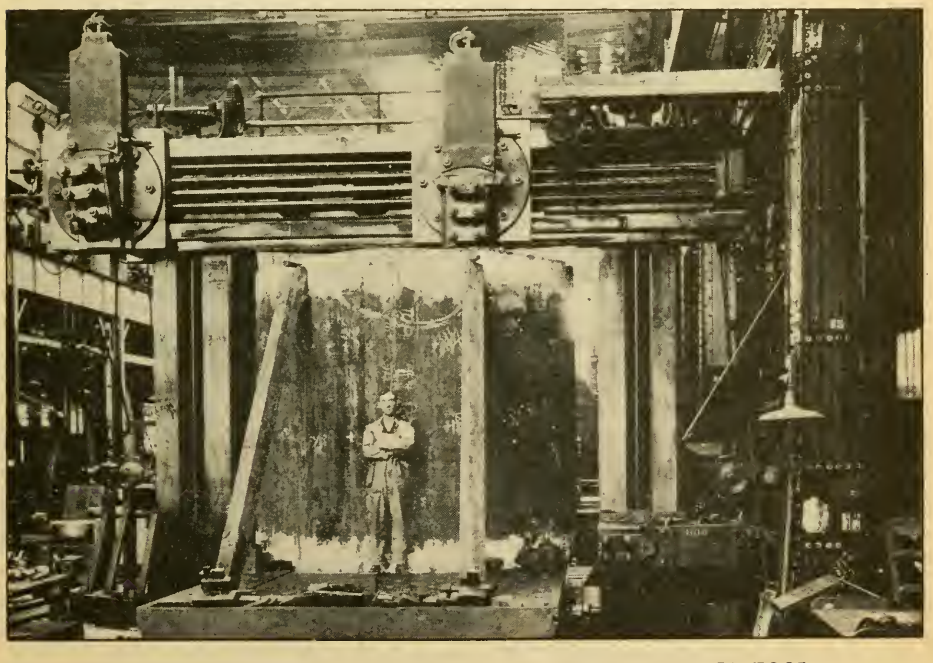

FIG. 10—MODERN PLANER HAVING HIGH SPEED STEEL TOOL

Osmond and Carpenter; namely: Chromium and tungsten lower the carbon content of pearlite, thus accounting for an excess of free carbides seen in annealed high speed steel of 0.60 - 0.70 per cent carbon. This is further partially verified by microscopic examination, which shows at high magnification, a structure of the matrix resembling very fine pearlite with no excess ferrite. Furthermore, chromium and tungsten prevent separation of cementite, so that the rate of cooling has little effect. An increase in carbon content further lowers the transformation range, so that by heating to high temperatures and obtaining a complete solution of carbide, the transformation range is lowered below room temperature, resulting in the austenitic or polygonal structure whether cooled rapidly or moderately slow.

The red hardness is due to the conversion upon heating of the austenitic structure to martensite, which theoretically increases the hardness and which many investigators have found to be the case. Personally, the author has not found an increase, but has found that the hardness remained practically constant. In view of the extreme sluggishness with which the carbide goes into solution upon heating, it is natural to suppose that it will separate out of solution just as sluggishly upon reheating, thus accounting for the long time a high speed tool will run at red heat before failure. Commercial applications of high speed tool steel are shown in Fig. 7 to 10.

As a practical result of high speed steel we need only look around the manufacturing establishments of today and compare with similar plants 20 years ago. The development of the present rate of production has been the result of a contest between the steel manufacturer and the machine tool manufacturer, with the producer as an interested spectator. The supremacy has alternated between the two contestants: first, one having a tool steel capable of higher speed than the machine would stand, and the other retaliating by building a machine of ample strength and free from vibration which would withstand a speed capable of burning up the tool. At the present time, the manufacturers of machine tools leading, and the next advance must be made by the steel manufacturer. Personally, the author believes that a cutting alloy whose hardness is not dependent on carbon and which is unaffected by heat is the coming high speed tool. The realm of alloys has yet only been touched since the number of alloying elements available and the possible combinations will give an infinite number of resulting compositions out of which can be found, one alloy or range of alloys which will have the toughness and keenness of steel and the heat-resisting qualities, or red hardness, of the present day nonferrous alloys.

HEAT TREATMENT OF HIGH SPEED STEEL

By J. L. Thorne

THE art of heat treating high speed steel is the most important branch of the cutting tool industry of today. It is even of more importance than good steel, careful designing, or of any other individual step in the process of manufacture for the reason that heat treating is usually one of the last operations, and all the good qualities that a tool might have possessed are readily destroyed in a greater or less degree by improper heat treatment. Realizing the importance of this operation, close attention should be given to every detail which will enable the operator to insure reliable results.

Steel being the raw material from which all tools are made should receive careful study and that grade which is best adapted for the particular purpose in mind selected. Many steels on the market today have adopted what is practically a standard chemical composition. This composition was selected because for standard work it has proven itself to be good. However, let us not make the mistake of being too conservative by refusing to try any new steel or alloy which may possess merit to a high degree. From the heat treating point of view, it does not matter by which process the steel is made, either the crucible or electric. Both methods make good and poor steels, depending entirely upon the skill and knowledge which are used in its manufacture. In a general way the chemical composition of high speed steel is as follows:

	Per cent
Carbon	0.60-0.70
Silicon	0.20-0.30
Sulphur	0.025 maximum
Phosphorus	0.025 maximum
Manganese	0.25-0.35
Chromium	3.25-4.00
Vanadium	0.25-1.00
Tungsten	16.00-18.00

Before going further, it might be well to consider the effects of these different elements upon the steel.

Silicon when too high causes a brittleness by forming a silicon of iron which is not appreciably dissolved in the steel and acts in much the same manner as any foreign inclusion.

Manganese is of great benefit to the steel, in that it readily combines with the sulphur and reduces to a minimum the damage this element would do if left to combine with the iron. Manganese, however, is nearly always in excess of that needed to combine with the sulphur and the remainder unites with the carbon to form manganese carbide which is one of the compounds which in part hardens tool steel.

Sulphur, if left uncombined by the manganese would form a compound with the iron which would be of a very brittle nature. As stated before, however, it is seldom in excess of the manganese and is injurious for the reason that manganese sulphide does not enter into the solid solution, but separates out as an inclusion in the steel. Sulphur causes steel to be brittle

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A paper presented before the Philadelphia Convention. The author, J. L. Thorne, is metallurgist, High Speed Steel Tool Corp., New York.

when hot, and if too high it is impossible to work the steel through the rolling mills and necessarily scraps the ingot.

Phosphorus unites with the iron to form a phosphide which often segregates and causes the other compound, such as the carbides, to become segregated, and it is said to be one of the chief causes of ghosts lines in steel. Phosphorus also causes the steel to be sensitive to shock.

Chromium does not materially alter the critical range, although it has been claimed to slightly lower the upper critical points. This element in conjunction with the carbon is mainly responsible for the extreme hardness of high speed steel. It is very influential in causing the steel to be hard on relatively slow cooling after being heated through the critical range, and it also imparts a secondary hardness on being reheated to a temperature under the critical range.

Vanadium was originally used as a scavenger of the steel to remove in the slag impurities and to reduce the amount of nitrogen held occluded in the steel. However, it is now proven that this element adds some very desirable qualities to the steel. It increases the elastic limit and greater resistance to wear and shock, allowing the steel to have a higher cutting rate when properly heat treated.

Tungsten slightly raises the critical range and unites with the carbon to form a double carbide. This element increases the desirable effects of chromium and imparts the high degree of red hardness which makes our high speed steel so valuable.

While this does not begin to exhaust the effects due to these various elements on the steel, it, in a general way, gives some idea of what the steel is composed and why the various elements are added. It also explains why the tool manufacturer lays as much stress as he does on the importance of purchasing steel of a specified analysis. On the whole the chemical analysis of the steel has no direct bearing on the heat treatment it will receive, aside from the fact that these various elements cause a change in the position of the critical range. The critical range itself is of secondary importance. The main fact which the heat treater should know is the temperature necessary to cause the various elements to enter into the solid solution and form a homogeneous compound. The following treatment is for the usual high speed steel on the market and as the composition varies with higher or lower percentages of alloys, the heat must be varied to meet the new conditions. With high speed tools which are cast to shape the heat treatment is altogether different in every way, from that described. It was because of our trying to heat treat cast tools in the same manner as we had formerly heat treated tools made of bar stock that we had encountered many failures and very uniform results. After a careful study of our cast tools, a new method for heat treating was worked out.

To illustrate some remarkable instances of what improper heat treatment may cause even with a high-grade metal, it may be well to give some of the results resulting from the usual heat treatment given high speed steel on cast tools and compare them with the results now obtained using an altogether different method. In heat treating tools cast to shape as ordinary high speed steel we found, as did many others, that breakage was very high, due to hardening strains and to the reason that cast tools do not have the fibrous structure that steel which has been hammered and rolled has, and, of course, if no corrective measures are taken, is of a brittle nature. This has been overcome by heat treating and in course of time, when some existing experiments have

been completed showing the relation of cutting ability to results from impact tests, tensile strength and elastic limit in conjunction with the hardness of the tool, we hope to present this information for your consideration.

Even with our limited knowledge of the cast iron tool industry, we have obtained cutters which will uniformly do the following work—a 6 x 1-inch milling cutter was used and the material cut showed a shore hardness of 38, the speed was 83 revolutions per minute or a cutting speed of over 130 feet per minute, depth of cut 1-inch feed, 16 inches per minute. This means we can remove 16 cubic inches per minute, or one cubic foot in little over one hour and a half.

Heat treating of commercial high speed steel consists essentially of first preheating the tool; second, raising it to the high temperature; third, quenching, and fourth, reheating, drawing or tempering. To accomplish these four operations successfully the form of the furnace should be carefully considered in its relations to the type of the tool to be hardened. For the purpose of this article, we will take into consideration such tools as are properly hardened in an oven-type furnace. This would include all milling cutters, blades, forming tools, etc., which are to be hardened all over.

The purpose of preheating is to raise the temperature to some point below the critical range, so that on its introduction into the high temperature furnace, it may acquire that temperature as quickly as possible. While it is necessary to leave the tools in the preheating furnace for some little time, care must be used that as small an amount of scale as possible is formed on the tool. The reason for this is that the scale when heated to a relatively high temperature is reduced again by the carbon of the steel and causes a decarbonized surface. There are many cases where steel has been condemned for this soft or discarbonized surface which was entirely due to an improper atmosphere within the furnace, this causing the scale. It has been found that the smaller tools of delicate shape could be preheated to high temperature as 1700 degrees Fahr. with good results, as it is not necessary to hold these pieces in the high temperature furnace for as long a time as would be necessary had the temperature been lower in the preheating furnace. In general, experience has proven that the higher preheating temperature gives better results than by following the older methods which use approximately 1500 degrees Fahr. for all preheating work.

The main points to be considered in the preheating furnace are: first, uniformity of heat; second, temperature to which the piece is to be raised; and third, the atmosphere within the furnace to obtain the least possible amount of oxidation of the tool. In preheating the tool, it should be brought to the temperature slowly, as this will eliminate the danger of checking the steel due to the uneven expansion of the tool. This is especially true of tools which are not of uniform cross section. From the preheating furnace, the tool is now transferred as quickly as possible to the high temperature furnace.

The object of the high temperature furnace is to cause the various elements in the steel to enter into a solid solution in the quickest possible time. The reason for haste is that as soon as the steel passes the critical range, grain growth sets in and the smaller we can keep the grain and at the same time acquire a homogeneous solution, the better service we may expect from the tools. Excessive grain growth causes brittleness in the tool and drawing even at high temperature cannot correct this, although it may mitigate the brittle nature to some extent. On account of this grain growth, the preheat-

ing should be as high as possible but lower than the critical range and the temperature of the high heat furnace considerably higher than that to which the tool is to be brought. For ordinary high speed steel a furnace temperature of not less than 2350 degrees Fahr. and as soon as the operator is able, this should be raised to 2375 degrees Fahr. or even higher. At this temperature the steel would soon be destroyed if left for any considerable time, and must receive careful attention and removed the instant the fine cutting edges acquire the proper temperature. The usual method to determine the proper time to remove the tool is to watch for the metal to sweat or small bubbles to appear on the surface of the tool. This method is good, but a better way for the careful observer is to watch the thin section of the tool and when the tool is ready to be removed a faint but noticeable intensity of color is observable. This increased intensity lasts but a very short time and if not observed, there is danger of the tool being overheated. It resembles in many respects the recalescence of plain carbon steel and is no doubt due to some changes taking place in the steel. The tungsten carbide will go into solution at a temperature much lower than has been recommended in this paper, but it is sluggish and to get it in solution takes time, allowing grain growth, although for the heat treater who has had little experience with high speed steel it is no doubt safer even if it is at the expense of the cutting ability of the tool.

It is of prime importance to heat cutting edges to get even uniformity, etc. To accomplish this, it is necessary to resort to many little tricks. All tools should be moved so that both sides shall attain the same temperature and for milling cutters, the writer has found that a block of pure nickel upon which they may be placed so that the cutting edges extend over the edges of the block assists in bringing the tool to a uniform heat. Tools which have a large and small cross section may be brought to heat evenly by protecting the thinner sections with asbestos for a portion of the time and removed so that all parts acquire the temperature necessary at the same instant. Angular cutters may be placed with the thin section next to the hearth bottom and are thus protected by their own mass and the thin sections are the last to acquire the necessary temperature.

Where many pieces are treated daily, the scale from the tools falls to the hearth and in the high temperature soon fluxes with the hearth to form a thick slag which does not help in heat treating and more often damages the fine cutting edges by promoting fusing of the steel. This slag often adheres to the tool after quenching and when it is sand blasted enough to remove this slag the cutting edges often suffer. When the hearth gets bad a sheet of asbestos covering the hearth will help considerably, although it requires renewing almost daily. In connection with the hearth, it has been found that carborundum is much better than the ordinary fire clay. The cost is two to three times as much, but gives nearly ten times as much service. In one heat-treating room the bottoms made of fire clay lasted on an average ten days. Carborundum hearths were tried and they gave better than three months' service. This, when the time lost in renewing the hearth is taken into consideration, more than paid.

Another source of trouble in the high temperature furnace is protection tubes to withstand a temperature of 2300 degrees Fahr. or higher. Most of the alloys on the market fail to stand up for any time at all and the refractory tubes have numerous faults. In the first place, it is hard to introduce a new protection tube into a hot furnace without first preheating on account of

breakage, due to the expansion of the tube. Even when put in a cold furnace and brought up to heat with the furnaces, they sometimes break for this reason. Another bad feature is that they are easily broken by being struck by the work in the furnace. As a substitute for the various protection tubes on the market using pure nickel tubes made from nickel bars with the holes drilled or bored is suggested. Cast nickel tubes were tried and while they were far superior to any that had been used before, they gave less than half the service the bar tubes gave and were more or less porous. The bar tubes have given service for three to nine months where the temperature used was from 2350 to 2385 degrees Fahr.

The tool having been brought to the desired temperature and the steel being in a solid homogeneous solution, it is necessary to quench the tool so that it is cooled quickly, thus the complexed hardenites do not have time to separate out and acquire that form in which the steel would be soft. Fortunately for the heat treater this takes place in high speed steel at a comparatively slow rate and even cooling in air is rapid enough to retain these hardenites in the form that will render the steel hard. However, to follow this practice a large amount of scale forms which reduces the size of the tool, causes pitting and in many ways impedes subsequent operations, however, it is still sometimes used, more especially in Europe. To overcome these objections the tools formerly were immersed in oil when removed from the high temperature which cooled fast enough to keep the steel hard. There are many objections against the use of oil, however. Some of these are: First, the oil often takes fire when large quantities of hot metal are quenched and unless expensive cooling devices are installed is dangerous. Second, the oil cools the tool too quickly and often causes the tools to check, especially when of uneven cross area. This is is especially true if the oil contains moisture and water often gets into the oil from the water jackets usually employed to keep the oil cool. Third, the oil becomes spilled or drips off the tools when they are removed and in this respect is dirty and causes the floor to become slippery, which is dangerous to the workmen. For these reasons as well as others not mentioned, heat treaters have discarded oil for high speed steel to a large extent and have substituted various salt baths which have a relative low melting point and are soluble in water. This bath should be kept at a temperature of about 1100 to 1130 degrees Fahr. The merits of this method of quenching eliminate the danger of checking the steel as the change of temperature from the high temperature furnace to that of the bath is not as great as in the case of oil and the amount of contraction and strains set up in the steel is correspondingly less. The heat is conducted away from the tool more slowly in the salt bath than in oil, but fast enough to retain the hardenites in their proper form. As soon as the steel has acquired the temperature of the bath, it is removed and allowed to cool to some point below 650 degrees Fahr.

The tool is now hard but contains the strain set up in quenching and the full red hardness has not been brought out to the maximum. To get these results it is necessary to temper or draw the tool. This may be done in the same salt bath or one kept especially for the purpose. Experiments conducted to determine the proper drawing temperatures showed the following results as the temperature of the draw increased from 350 to around 700 degrees Fahr. the scleroscope showed a decrease in hardness. From this point up to nearly 1200 degrees Fahr. the scleroscope showed an increase in hardness

with the increase in temperature. Some metallurgists attribute this to the fact that it is during this latter range of temperature that the red hardness of high speed steel is developed. While the scleroscope showed the steel to be harder at, say 1100 degrees Fahr. than at 700 degrees, a test made with a file showed the tool to be softer. On actual cutting test the higher drawing temperatures always gave better results. This shows conclusively that neither scleroscope nor the file alone will give any indication of what a tool will do in actual cutting tests; but if they are used together they will indicate to a large extent just what may be expected of them. For general purpose a drawing temperature of 1130 degrees Fahr. is recommended, but if the operator is positive that his temperature recorders are correct, this drawing temperature may be carried up to 1175 degrees Fahr. Exceeding this temperature very much again causes the steel to become softer until the annealed condition is approached.

In conclusion it may be said that with care in handling and with a reliable pyrometer equipment, anyone should be able to heat high speed tools and obtain creditable results. The quenching and drawing in molten salts eliminate many of the dangers which formerly followed the old practice of using oil for these two operations. Lead baths have been used as a means of drawing, but on account of the lead adhering to the tool, particularly if there be scale on the steel, and the difficulty of its removal makes its value a doubtful one. Lead is also rather too good a conductor of heat to be the ideal bath for these operations. The exhausted cyanide bath will answer very nicely for both the quenching and drawing baths.

DISCUSSION OF MR. THORNE'S PAPER

MR. REARDEN: What would you consider in drawing would be the proper temperature for the bath in oil?

MR. THORNE: Personally, I would not use oil. I would use a bath at approximately 1100 degrees Fahr. for quenching.

MR. REARDEN: Suppose that is not available. Suppose you use the oil?

MR. THORNE: I would have the temperature of my oil at least 125 degrees Fahr.

MR. REARDEN: What would be the final point for a cutter edge three-quarters inch in diameter, 4 inches long?

MR. THORNE: I would say, off-hand, 1130 degrees Fahr. depending, of course, on the initial heat. If you have the tungsten entirely in solution, 1130 degrees Fahr. and perhaps even higher would give very good results.

MR. KANE: In protecting the thin parts of tools will it be a whole lot easier to take a cold bar and hold over the part you want to keep down where it has a tendency to heat faster, instead of wrapping with asbestos?

MR. THORNE: It all depends on the shape of the part that you are trying to protect. Any method that will hold the heat back. It was not the idea to wrap the piece, but simply laying a piece loosely over it in protecting it, I have often found even that simple method would hold the heat back, but any other method that would hold the heat back, if you can spot the heat with a rod or anything of that sort would answer equally as well. The main thing is to get it to come to an even temperature at the same time, just before quenching.

MR. REARDEN: The oil being at a lower temperature than 125 degrees Fahr. would probably cause the cutter to crack, would it not?

MR. THORNE: It would certainly be more of a severe shock set up. What we call quenching strains would be more apt to cause checking than the other method.

MR. JENSEN: I would like to ask the question—I run my steel up to 2250 degrees Fahr. and still it is soft, so you can file it with a file. On heating it up again and quenching it in oil it cracks. What is the trouble?

MR. THORNE: There are several things that might be wrong. It may be that you are not getting your steel in solution. It may be that your atmosphere is bad and you are decarbonizing the surface. On reheating, without annealing and quenching in oil, you very often get the checking due to strains set up by a double quench without relieving any of those strains. The mere fact of reheating up to a hardening heat without a prolonged annealing does not seem to relieve those strains, although you might think it would.

MR. THOMPSON: In quenching from high heat in oil is it better to hold the tool steady in the oil or set up a motion?

MR. THORNE: I personally discontinued the use of oil about five years ago, or perhaps six years ago, but up until the time that I discontinued using oil I found that I had less distortion by holding the piece still, and the piece is cooled rapidly enough, even at that, unless a piece is very large, so it is not necessary to rotate it in the oil bath.

MR. STENGER: I have been told of wonderful results that have been obtained by carbonizing high speed steel, also by covering the work with cyanide compounds when heating in the higher heat. I am wondering if Mr. Thorne could tell us something about carbonization of high speed steel and what effect it has.

MR. THORNE: I can tell you my experience with it is a very simple matter. It was disastrous, although I don't doubt but that a high speed steel can be carbonized or that it can be hardened, but at the time I tried it and was fooling with that stuff it was very disastrous to me.

VOLUME CHANGES IN THE HEAT TREATMENT OF STEEL

By Leslie Aitchison

CHANGES of structure occur during the heating and cooling of steel are of great, in fact essential, importance, and are the fundamental facts underlying the possibility of the changes in mechanical properties which can be brought about by heat treatment. Without going too far into the subject it may be desirable to mention the most essential features of the changes which occur. If a carbon steel is heated, a certain definite alteration occurs in its constitution when the steel reaches a predetermined and fixed temperature or very narrow range of temperature. The change which occurs at what is known as the "lower critical" or "carbon change" point, which is found at a temperature of about 730 degrees Cent., consists of the formation within the steel of a solid solution. At ordinary temperatures the steel, if it has been cooled normally, contains a constituent known as pearlite, which is a mixture of fixed proportions of iron and iron carbide.

When this mixture is heated to the lower critical change point it is transformed from a mixture into a solid solution. The two constituents of the mixture, iron and iron carbide, mutually dissolve one in the other to produce a solution of iron carbide in iron. The transformation takes place at a definite temperature and occurs almost instantaneously. The resulting solution is a true solution, and the only difference between it and, for instance, a solution of sugar in water, is that the latter is liquid and the former is solid. If the solid solution is heated to a higher temperature than the critical point, it will dissolve into itself whatever other constituent may be present in the steel either excess iron (ferrite) or excess carbide (cementite), until finally, when the upper critical point is reached, the whole of the steel consists of solid solution.

The changes produced in the steel by heating, of course, have a considerable effect upon the mechanical properties of the steel, particularly if it is cooled rapidly from a high temperature. There are other changes, however, which take place in the steel as a result of the constitutional changes described above, and these are related to the volume of the steel. The solid solution which is formed at high temperatures has a different specific gravity from that possessed by the mixture from which it is formed. The steel in passing from the condition of a mixture to that of a solid solution contracts and occupies a definitely smaller volume while in the form of a solid solution. Similarly, when the reverse structural change takes place, there is an opposite volume change, an expansion, since the mixture occupies a larger volume than the solid solution.

It must be made perfectly clear that these changes of volume always accompany the corresponding changes of structure and that they cannot be suppressed or eliminated. They are essential properties of the steel. Thus, whether the steel is cooled rapidly or slowly, the volume changes will occur, provided that the constitutional changes take place also.

The changes of volume described above necessarily occur at the critical temperatures. Before proceeding to discuss what these changes mean, it is desirable to mention that during the heating and cooling of steel other volume changes take place. These, of course, are the comparatively simple

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and regular changes of volume which occur when steel is heated or cooled, due to ordinary thermal expansion and contraction. It is well known, of course, that steel expands when it is heated and contracts when it is cooled. Moreover, the extent of the expansions and contraction is found to be more or less regular over the whole range of temperature between zero degrees Cent. and the critical temperature. The normal changes mean, therefore, that when heated to any temperature the steel expands and when cooled it contracts. The abnormal changes due to the alterations of structure mean that a steel contracts when heated through its critical temperature and expands when cooled. In other words, the abnormal and the normal volume changes act in opposite ways. The nature of the complete changes is shown in Fig. 4, which represents all the alterations of volume which occur when steel is heated or cooled from room temperature to 1000 degrees Cent.

The above facts have a very considerable influence upon the heat

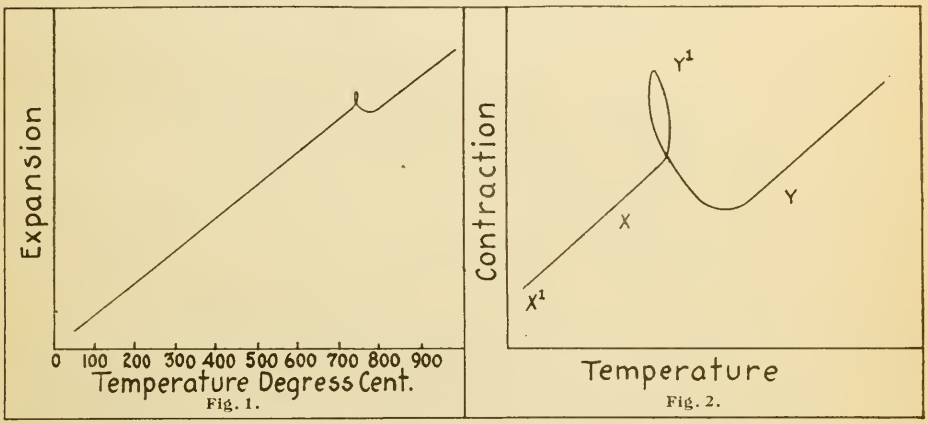

FIG. 1—CURVE WHICH SHOWS THE ALTERATIONS IN VOLUME WHICH OCCUR WHEN STEEL IS HEATED OR COOLED FROM ROOM TEMPERATURE TO 1000 DEGREES CENT. FIG. 2—DIAGRAM ILLUSTRATING HOW SOME LAYERS CONTRACT WHILE OTHERS EXPAND WITH THE RESULT THAT STRESSES RESULT.

treatment of steel. Before they can be discussed really profitably, however, it is desirable to examine the processes of treatment rather more carefully. It may be said at once that the only heat treatment operation which is affected seriously by volume changes is the hardening process. This process, as is well known, consists in the more or less rapid cooling of the steel from a temperature as near as possible to its upper critical point. At this temperature the steel consists entirely of solid solution, and the aim of the cooling process is to retain this solid solution more or less intact during the time that the steel cools to atmospheric temperatures. Unless this result is achieved, the steel is not hardened properly.

It is well known that all steels do not harden to the same extent nor with the same ease. Some steels have to be cooled in water, others in oil, while others again will harden if cooled only in air. These facts point to the conclusion that every kind of steel has its own particular critical rate of cooling which must be achieved or exceeded if the steel is to be hardened. If the steel is cooled at a slower rate than the critical, the solid solution

which is formed at the high temperatures will be wholly or partly decomposed during cooling.

It is equally well known that during the cooling of a piece of steel, or for that matter of anything else, the rate of cooling of the interior is slower than that of the exterior, and therefore, that, whereas a piece of steel when quenched may cool on the outside at a speed equal to or greater than the critical rate of cooling required to harden the steel, the interior of the same piece cools at a rate lower than the critical. The result is that the exterior of the part is hardened and the interior is not hardened. As a consequence, the solid solution which existed at high temperatures on the outside of the part remains intact during the cooling down, but that which existed in the interior of the part is decomposed either partially or completely according to the depth of the particular point below the surface. The above facts are quite familiar under the term of the "mass effect" in hardening.

It is now time to inquire in what way the volume changes which occur during the heating and the cooling of the steel affect the steel during hardening. It may be said at once that the only volume changes which affect the steel in any adverse way are the abnormal changes occurring at the critical temperature in consequence of the alteration of the structure of the steel. The ordinary volume changes due to normal thermal expansion and contraction have no detrimental effect upon the metal. Imagine the case of a piece of steel, either spherical or cylindrical. In the latter case, imagine the cylinder to be very long, sufficiently so that by concentrating attention upon the steel at the middle of its length, the effects of the ends of the cylinder may be neglected. When the steel is hot it is at a uniform temperature throughout. Let it be taken out into the air and allowed to cool as it will. There will be at any time a gradient of temperature from the inside to the outside of the piece, so that every layer will be slightly hotter than the next exterior layer and slightly cooler than the next interior layer. Suppose that the cooling starts from a temperature well above the lower critical point. During the time that the steel is above this temperature every part of the steel will contract more or less uniformly, the outer layers always contracting upon the inner because the latter, being at the higher temperature, will have contracted somewhat less than they will when temperature equilibrium has been established. That is, however, of little importance.

When the outermost layer cools down to the critical temperature it will suddenly expand and then continue to contract once again according to the process of normal thermal contraction. Its volumetric alterations are shown in Fig. 2. The second layer will go through similar alterations of volume, as will each successive layer. After a few layers have passed through the complete change, the outermost layer has cooled distinctly below the critical temperature and therefore has a volume distinctly less than it had at the time that it passed through the critical volume changes. Its volume may be indicated satisfactorily by the position X on the diagram in Fig. 2. A layer a little deeper in the specimen will have a volume indicated by the position Y in the figure. When the temperature of the steel has fallen a little lower, the volume of the outside will be say X^2 and that of the deeper layer will be Y^1. In other words, the outside has contracted a little and the inside has expanded. This is bound to mean that the outside of the part is stressed to some extent. The value of the

stress will probably be quite small, since the steel is cooling normally and no harm is likely to be done. Nevertheless, some stress by necessity will be exerted on the outermost layer of steel.

The next condition to consider is slightly different. Suppose that the steel is quenched at a rate sufficiently high to harden the steel. This means that the rate of cooling is high enough to retain the solid solution intact and to prevent it from decomposing. Each successive layer of the steel, therefore, avoids the expansion, and the only change that will occur will be that due to the ordinary normal thermal contraction of the part. Suppose, however, that the steel suffers from mass effect and does not harden completely through. There will be abnormal volume changes in one part and not in another part of the piece of steel.

In the outside there is no structural change and as a result no abnormal volume alteration. In the interior both structural change and consequent volume change occur. It will be well, therefore, to examine more closely the results of these alterations.

Since the outside of the material undergoes no structural change, its volume, particularly at temperatures near to the critical point, will be very much less proportionately than the volume will be if it has undergone a normal expansion. On the other hand, the interior of the part in which the structural changes have occurred will have expanded, and consequently will put a considerable stress on the outside nonexpanded layers. The stress which is put upon the steel on the outside will be greatest at the time that the interior layers pass through the critical range, and will not be so marked when the temperature has fallen almost to the atmospheric. It must be remembered also that since the whole piece of steel is being cooled rapidly, the temperature of the outside layer will have fallen to quite a low value by the time that the interior portions have fallen to the temperature of the critical point. This means that the outside layer will have contracted considerably in accordance with the ordinary laws of thermal expansion and contraction, and consequently will feel the effect of the expansion of the internal layers at the critical temperature more than it would if the normal thermal contraction had not taken place. The result of the contraction of the outside and the expansion of the interior will be the exertion of a considerable stress upon the outside layers of the steel, particularly intense at the moment at which the interior part is passing through the critical point.

The stresses set up in the exterior layer during the operations of quenching may be very considerable. There can be no doubt that it is these stresses which are mainly responsible for the production of cracks in various kinds of steel during quenching. It is essential, therefore, that every precaution should be taken to avoid the production of the stresses. Although the actual stress itself cannot be eliminated entirely in any steel which suffers from the mass effect during hardening, it is possible to take precautions to avoid this stress being concentrated or accentuated by the conditions of the surface of the steel.

OBSERVATIONS MADE IN THE HEAT TREATMENT OF ORDNANCE FORGINGS

By Paul E. McKinney

IT IS a notable fact that in the discussion of heat treatment problems most authorities and writers give prime consideration to the question of chemical analysis and finish of material in their study of the material under treatment. The major considerations which are given as the basis for analysis are limited to these points alone with the minimum consideration given to the numerous other factors which have a very material bearing on the subject of heat treatment. Manufacturers of steel know that the analysis of the finished product and the surface condition of the billet or bar of fabricated steel does not tell the whole story as to the quality of the material. Yet the heat treater has not given the fullest consideration to many of these factors which are not apparent from the results of analysis or a general examination of the material but which have a distinct bearing on the serviceability of the finished article and also the behavior of the material under heat treatment.

While the average metallurgist of today has in a large measure abandoned the old beliefs and prejudices which existed in favor of certain brands of steel, it is still well known that with analysis and general surface appearance of the material identical, certain brands of steel are far more satisfactory both from the standpoint of the heat treater, the engineer and the user of the finished product than other brands of identically the same characteristics from the basis of chemical laboratory analysis. There is undoubtedly a reason for the superiority of one brand over the other, based on characteristics due to different methods of manufacture and of handling the material before it reaches the heat treater.

The basis for most specifications for steel touch lightly on many important characteristics but often lay undue stress on chemical analysis prohibiting slight deviations from standard composition, permitting the acceptance as good material of anything which simply falls within the limits of composition and is reasonably free from defects which are apparent to visual examination. Some specifications may have limitations as to discard from ingot or other arbitrary requirements but the science of metal studies has not reached the point where some conditions more fatal than slight deviations in composition are specifically guarded against.

While in the production of molten steel there are only a few processes utilized commercially, the modifications and degrees of refinement of practices in each process as carried out in different commercial plants are innumerable and the gradations in quality of product from various plants are too numerous to mention, the production of some plants presenting certain distinct characteristics as compared with the production from other plants. A general examination of the product from all of these various modifications of steelmaking processes would result in two general classifications of material when based on chemical analysis, namely: Acid and basic steel. Strong opinions exist regarding the superiority of one grade of steel for given purposes over another grade without consideration of the fact that there is well made steel and poorly made steel produced by each process.

A few of the factors which have serious bearing on the quality of

A paper presented before the Washington Chapter. The author, Paul E. McKinney, is chemist-metallurgist, United States Naval Gun Factory, Washington.

steel and which are not apparent from a casual examination of inspection reports of raw material are the following:

Method used in refinement of steel
Metallurgical control of conditions of slag
Methods of introducing ferroalloys, degasifying agents, etc.
Condition of metal previous to tapping from furnace
Temperature of metal during refining and finishing
Size of nozzle used in teeming of ingots
Method of pouring ingots
Size of ingot used for given purpose
Type of ingot used as regards chilling effect, etc.
Rate of speed in pouring ingots
Temperature of metal entering the ingot
Shrinkage of the ingot on cooling
Behavior of the ingot during solidification

Regardless of the process used, the production of steel is based primarily upon the melting of a charge of raw material properly proportioned as regards composition to have sufficient iron combined with carbon, manganese, etc., to produce a boiling action during the early stages of the refining operation, which action tends to refine the crude material as originally melted and to bring it into condition for the succeeding stages in the operation consisting of recarburization and the addition of ferro-alloys to complete the refinement, degasifying the steel and bringing it to the proper composition. Modifications innumerable are introduced into the practice depending upon the results desired for the particular heat, but the prime object is to produce a finished molten bath homogeneous in character and as fully refined as possible. In this discussion we are precluding from consideration entirely such grades of steel as are used for very ordinary commercial purposes and limiting the discussion to such steels as are ordinarily used in the production of forgings and other articles subject to heat treatment.

In the production of large forgings, such as are used for ordnance purposes, many factors entering into the steel melting practices have a very marked influence on the behavior of the material and the ability of the same to withstand the rigid physical tests necessary to insure their serviceability for the purposes intended. The degree of refinement previous to teeming, the temperature of pouring, the conditions under which the steel is poured, the type of ingot, and numerous other factors which might be considered negligible factors in the production of ordinary commercial product most seriously effect the results obtained in the production of ordnance forgings, and with these factors other than normal the heat treater working in the final treatment of such forgings has before him an insurmountable task. Strictly speaking, it is impossible to produce a steel in the molten condition which is so highly refined that no further reaction takes place. Reactions to a limited extent continue in the molten steel up to the time of solidification.

With conditions other than normal as regards refinement in the furnace, high pouring temperature or completion of the reactions between the added ferro-alloys and the molten bath, these reactions taking place in the molten metal during the process of solidification are very pronounced, especially in the case of large ingots which cool at a relatively slow rate. The reactions taking place during solidification of a steel,

N. C. F. 316.

HEAT ON ROOF 67
" " " WALLS 67
" " " BOTTOM 124

MELTER'S REPORT

ELECTRIC FURNACE NO. 1

HEAT NO. X
ORDER NO. Y
DATE April - 1921

C. R. Rodgers — MELTER
J. J. Jackson — 1ST HELPER
NIGHT / DAY

CHARGE AND ADDITIONS.

Material.	Weight.
Nickel steel turnings	6000 lbs.
Chrome nickel steel scrap	8000
ORE 60% Fe	600
MANGANESE, CARBON FREE	
MANGANESE, 80 PER CENT	60
SILICON 50%	60
SILICON FOR SLAG 50%	25
CHROME, CARBON FREE 60%	160
CHROME, 2 PER CENT	
CHROME, 6 PER CENT	
NICKEL	95
VANADIUM	
ALUMINUM	2
	14,737
LIMESTONE	270
LIME	
COKE	
SPAR	20
GRD. ELECTRODE	20
GRD. ELECTRODE, IN LADLE	
	310
DOLOMITE	
MAGDOLITE	600
MAGNESITE	
FIRE CLAY	
GANISTER	
TAR	
MOLASSES	

ANALYSIS.

	C.	Si.	S.	P.	Mn.	Ni.	Cr.	Va.	Cu.
REQUIRED	.35 .45	.20 .30	Max. .050	Max. .050	.40 .60	2.20 2.40	.80 1.00		
OBTAINED	.43	.21	.031	.034	.50	2.43	1.14		.28

PRELIMINARY TESTS.

	To Lab.	Rec'd.	Delay.	C.	Si.	S.	P.	Mn.	Ni.	Cr.	Va.	Cu.
No. 1	1:10	1:25	15	.26			.024					
" 2	1:40	3:00	1 hr. 20 min.						2.12	.56		
" 3	2:15	2:40	25	.34								
" 4	3:20	3:45	25	.40								
" 5					SiO_2	S	P	Mn	Fe			
" 6	Final	Slag			29.76	.080	.017	1.61	7.05			

TIME OF HEAT.

Time.		Hrs.	Min.		Current.
6:25	PREVIOUS HEAT TAPPED			METER READING BEGINNING	265300
8:10	BEGAN CHARGING	1	45	METER READING AFTER MELT DOWN	268900
9:20	FINISHED CHARGING	1	10		
9:20	CURRENT ON			METER READING AT FINISH	270800
12:35	MELTED	3	15	TOTAL KWH	5500
1:25	FINISHED SLAGGING		50		
3:20	TAPPED	1	55	KWH PER TON	746.27
	TIME OF HEAT	7	10	LADLE NO. 2	

ELECTRODE NO. 1 O.K.
ELECTRODE NO. 2 O.K.
ELECTRODE NO. 3 O.K.

SLAG CONDITIONS Dark gray
POURING TEMP. OF STEEL IN LADLE 8 seconds
POURING CONDITIONS IN MOULDS Normal
HOW STEEL LAID IN MOULDS Quiet
ALUMINUM IN MOULDS None
PHYSICAL CONDITION OF INGOTS Good

PRODUCTION.

No. Ingots.	Size.	Weight.	Per cent
BUTT			
LADLE SKULL			
SCRAP			
LOSS			
TOTAL			
SLAG WEIGHT			

DELAYS AND CONDITIONS.

ROOF Bad
WALLS Bad
BOTTOM Tended to rise during later part of heat.
ELECTRICAL APPARATUS O.K.
MECHANICAL APPARATUS O.K.
WATER PRESSURE O.K.

Remarks: Necessary to tap heat before slag was in perfect condition due to trouble with bottom.

FIG. 1—DATA SHEET OR MELTER'S REPORT WHICH SHOWS COMPLETE HISTORY OF EACH STEEL HEAT MADE IN THE FURNACE

INGOT RECORD.

INGOT NO. Z HEAT NO. X DATE April - 1921 SHIFT 8 to 4

C	P	MN	SI	S	CU	NI	CR					
.43	.034	.50	.21	.031	.28	2.43	1.14					

SIZE OF INGOT 18" x 11'	TIME TO POUR 7 minutes		REMARKS.
TYPE OF MOLD Octagonal	RATE PER MINUTE 993 lbs.		Chrome nickel heat.
EST. WEIGHT 6950 lbs.	SKULL Heavy		
MOLD FULL Yes	SHRINKAGE 3"		
SIZE OF NOZZLE 1" dia.	SURFACE CONDITION Fair		
TYPE OF HOT TOP Sand			

Checked and found correct.

John Doe
Asst. Chem. and Met.

Richard Roe
Supervisor.

4—4619

FIG. 2—INGOT RECORD SHOWING SPECIFICATION OF EACH INGOT CAST FROM THE FURNACE

which is not in perfect condition, will produce the inclusions of metalloids which exhibit themselves during the heat treating operation as so-called ghosts, streaks, slag spots, flakes, woody structure, etc. It is believed that a close analysis of the conditions under which the material is produced will indicate beyond a doubt that such inclusions of metalloids are not due to mechanical impurities entering the ingot from the ladle but are due principally to the results of reactions which produce nonmetallic impurities during solidification. The general tendency of such impurities during forging is to form into different cleavage lines, spots and streaks and, if sufficiently pronounced, will produce a laminated condition with the laminations running parallel to the direction that the material has been forged, rolled or worked. Many alloy steels exhibit the effects of such inclusions to a much greater extent than carbon steels and show this pronounced lamination to an unmistakable degree, this being particularly true in the case of nickel steels or steels containing a rather high percentage of nickel.

The effects of inclusions and conditions due to imperfect melting practices are not noticeable in many grades of commercial steel such as bar stock, where test samples either before or after heat treatment are taken as longitudinal specimens, on account of the fact that the tendency of inclusions after rolling is to elongate themselves in the direction of the rolling. Longitudinal tests on this material will generally exhibit as good values as in the case of normal material, but a different story would be told if tests could be taken transverse to the direction of the rolling.

In the production of ordnance forgings, on account of the fact that the finished forging gets its maximum stress in a tangential direction, it is necessary to take test specimens from the forging in less favorable positions than in the case of commercial bar stock and similar materials, and therefore, the effect of imperfect melting conditions is clearly evident. The mass involved in the average ordnance forging at best defeats the nicety of grain refinement and heat treatment which is possible in forgings of smaller mass and even under the most favorable conditions as regards raw material, it necessarily follows that with disturbing influences, such as nonmetallic inclusions resulting from imperfect melting practices, the difficulties involved are very materially increased.

During the recent war many reputable steel producers experienced expensive failures in the production of ordnance forgings, due to the fact that attempts were made to utilize in the production of these forgings the same general practices as had previously been followed in the production of commercial forgings. Today it is becoming practically universally recognized that the production of a high-grade forging, such as is required for ordnance purposes, cannot be made by the activities of the heat treater alone but starts in the melting furnace, and that without the best raw material, the heat treater cannot perform the impossible feat of remaking the steel. While it is admittedly impossible to definitely specify standard conditions under which each grade of steel is manufactured, it is believed that a careful study by heat treatment engineers of the history of the material from its origin would very materially assist in clearing up many of the difficulties now experienced and that a move in the right direction would be made by the insistence on the part of heat treaters in general of being furnished with data showing the entire

N.G.F. 325

FORGING RECORD.

INGOT NO. 2 DISCARD TOP 30% BOTTOM 5%

SPECIFICATIONS 49-S-2d Alloy #1

SECT.	STUB	DR. AND PC.	NAME OF PIECE	TEMPERATURE AND TIME OF HEATING: CHARGED	TIME	REDUCTION PER CENT: U	E	M	DATE	FORGER AND SUPERVISOR
B-1 to	Z-CH		Air		9 hrs.					Smith
B-25	46	9509-1	flask heads	12:30 A.M.	15 min.	-	160	-	4/25/21	Jones

Numerous transverse cracks developed when ingot was first put under press. These cracks diminished somewhat with additional forging.

4—4609

FIG. 3—FORGING RECORD SHOWING DETAILS OF FORGING OPERATION AND THE EFFECTS PRODUCED

history of the material. This with a study of the behavior of the same during the heat treatment would within a very short time enable the trade to prepare specifications based on the actual results obtained from materials of varying characteristics.

As an example of the effect of melting conditions on an apparently good heat of steel, the following citation is given in a heat of electric chrome-nickel steel which has shown unusually bad characteristics regarding ability to stand the physical tests, the presence of foreign inclusions and other irregularities in the finished forgings. In this particular heat the analysis of the heat as shown in Fig. 1, would be classed as normal by any heat treater, the finished billets would be classed as acceptable, judging from Fig. 2, and all other requirements of ordinary specifications would be met, yet an examination of the heat record will indicate beyond a doubt that the melting conditions were abnormal in a number of respects, due to a furnace condition which in itself might appear immaterial but actually most seriously effected the final refining of the steel. These conditions would not be apparent to the purchaser of billets in any manner nor to the heat treater who attempted to heat treat the stock after forging and would probably result in one of those cases where heat treatment would be blamed as being faulty. Rejections would be excessive without any apparent cause.

By a study of the conditions which are abnormal in this heat, particularly the condition of the slag and the analysis of the slag, it could be seen readily that the material was at least of questionable quality. With normal melting conditions, the slag analysis should show a manganese content and an iron content not greater than 1 per cent in each case and the condition of the slag should be pure white. While the forging record of this heat, Fig. 3, shows the material to have a tendency to crack during preliminary forging operations, the condition of the finished billets in this case would not have indicated any serious trouble and without an examination of melting conditions, the heat treater would have been at a loss to explain the cause of trouble.

The above example is given for the purpose of demonstrating the possibilities of erroneous deductions which may be made when based on anything but the fullest history of the material. The science of heat treatment will be very materially advanced by the insistence on the part of heat treatment engineers of being furnished with the most complete data on the material which they are handling. It is believed that this is the key to successful heat treatment operations.

THE THERMAL TREATMENT OF CAST STEEL

By Alvin N. Conarroe

THERMAL treatment of steel includes all of the thermal conditions to which steel has been subjected from the time it has been cast until it is ready for shipment. If this treatment has been done wisely, the steel will be in the best condition to give good service under the widely varying conditions to which it is subjected in use. Since most steels are cast in some form before subsequent treatment, any defects or conditions inherent to this procedure are more or less reflected in the finished product. Thus, the subject of cast steel might be made to cover a wide range, but in this article will be limited to those steels cast initially to their final form, and, since a large majority of steel castings are made of medium carbon steel, mainly to hypoeutectoid steel.

Steel is essentially an alloy of pure iron, a ferrite, and a definite chemical compound of iron and carbon, cementite. Therefore, as the percentage of carbon increases, the amount of cementite increases up to the maximum solubility of carbon in iron at normal temperatures, which is about 1.7 per cent carbon. When steel in the liquid state solidifies, it forms a solid solution, or alloy. This solid solution is termed austenite and is homogeneous in character just after solidifying. As the percentage of carbon increases the temperature at which solidification takes place is progressively lowered, following in this respect the general law of eutectic solutions. This progressive lowering of the freezing point is continued until the carbon content has reached 4.3 per cent, when it rises again. However, this per cent of carbon has extended into the field of cast irons, to the eutectic ratio and is of no concern in the present discussion. As the solid solution of iron carbide in iron cools further, certain changes or transformations take place which are manifested by evolutions of heat at certain temperatures, causing a lag or break in the cooling curve of the material. The temperatures, at which these changes occur, are called critical temperatures and a proper understanding of their cause and position is important to the intelligent heat treatment of steel. All plain carbon steels, containing up to 0.35 per cent carbon, have three critical points; those from 0.35 per cent carbon to 0.85 per cent carbon, two; 0.85 per cent carbon steels show but one point, while those above 0.85 per cent show two points of transformation. These points are referred to as Ar_3, Ar_2, Ar_1, Ar_{3-2}, Ar_{3-2-1}, Ar_3cm, Ar_{2-1}, the "A" meaning a point of transformation and "r" coming from refroidessement, meaning cooling.

In a similar manner to the lowering of the solidifying point with increasing carbon content, the two upper critical points are lowered as the carbon increases, reaching a minimum and coinciding with the lower critical point at 0.85 per cent carbon, rising again with increase of carbon content. On account of the similarity of these transformations in the solid solution to the freezing of eutectic solutions, those steels containing 0.85 per cent carbon have been called eutectoid steels, those containing less carbon, hypoeutectoid, those containing more carbon, hypereutectoid. Eutectoid steel consists of but one microconstituent, when examined under the microscope, and it appears as grains containing alter-

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A paper prepared for the Philadelphia Convention. The author, Alvin N. Conarroe is chemist, National Malleable Castings Co., Melrose Park, Ill.

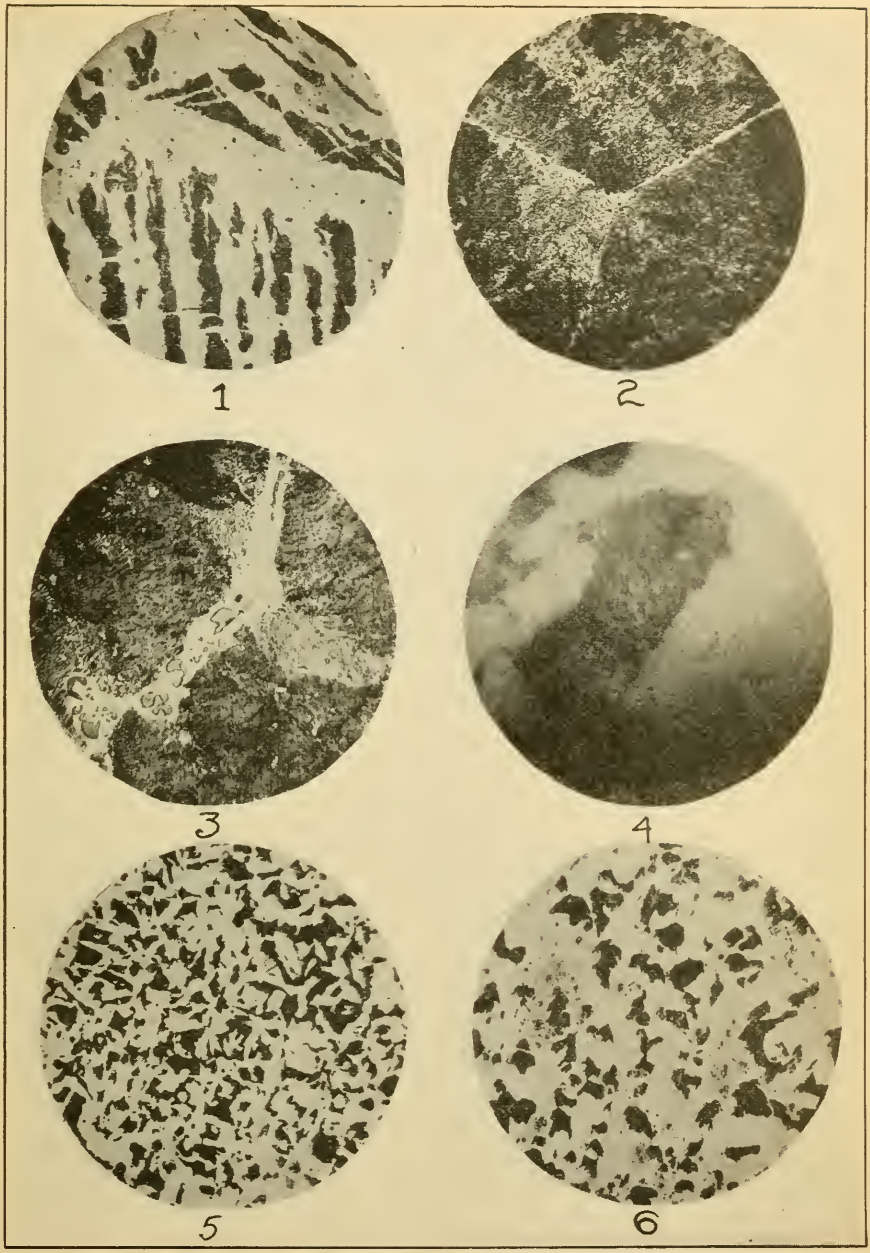

Fig. 1—Unannealed hypoeutectoid cast steel. X 50. Junction of two allotrimorphic crystals showing deposition of ferrite along cleavage lines of crystalline grains. Fig. 2—Ingot structure of cast steel approaching eutectoid composition. X 100. Junction of three large crystalline grains showing thin white ferrite lines marking grain boundaries. Fig. 3—Steel same as in Fig. 2 but cut from a segregated section. X 100. Shows broad ferrite band between grains, inclosing islands of manganese sulphide and manganese silicate. Also shows laminated structure in parts of pearlite areas, indicating segregation of eutectoid material. Fig. 4—Pearlite of hypoeutectoid steel X 950 showing laminated structure. Fig. 5—Underannealed hypoeutectoid steel X 100. Although the ferrite and pearlite are well distributed, ferrite still retains pointed needle structure resulting from incomplete absorption. Fig. 6—Overannealed hypoeutectoid steel X 100, showing structure resulting from overheating and cooling slowly past critical range. Sufficient time has been given for migration of ferrite to grain boundaries.

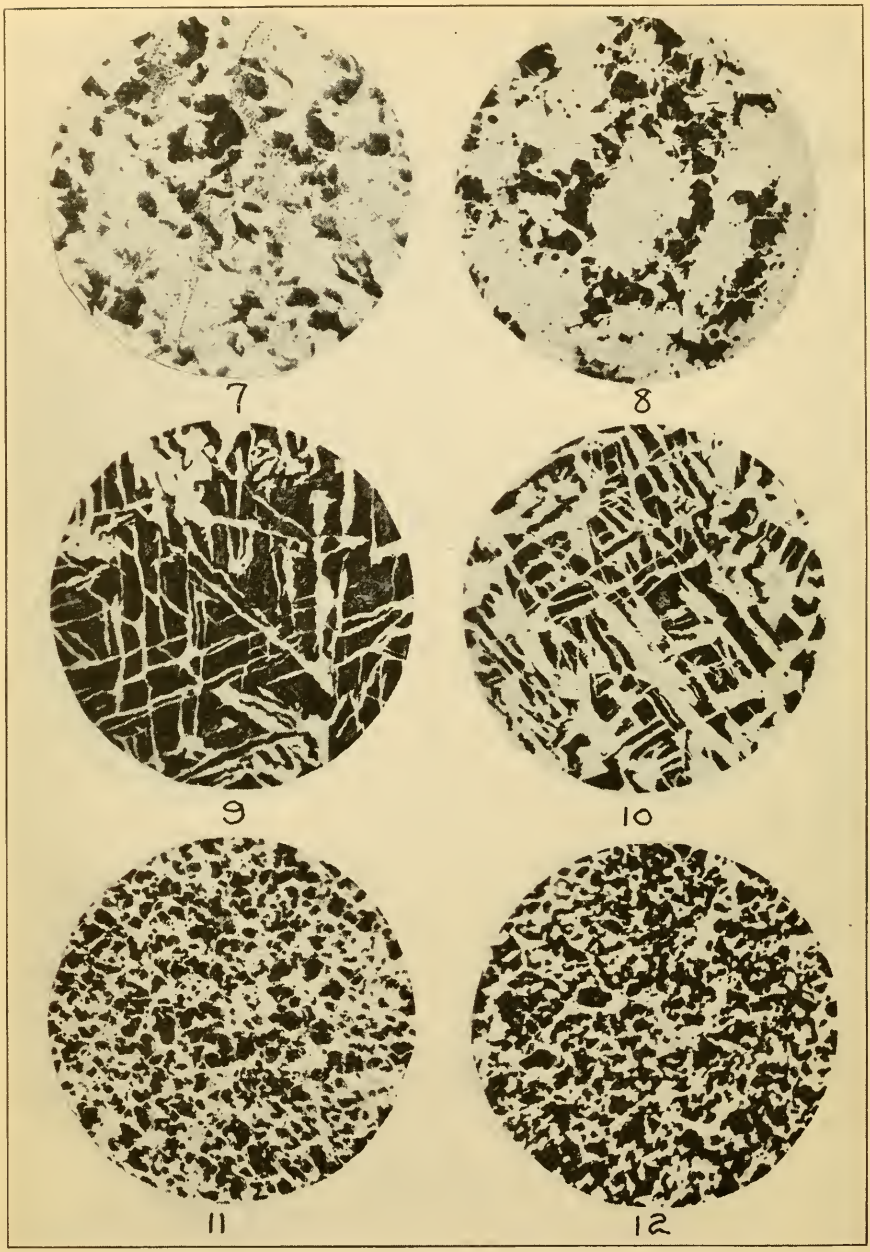

Fig. 7—Same condition shown in Fig. 6, however, metal has been strained before heating. X 100. Fig. 8—Structure developed by prolonged heating at fairly low temperature, within critical range, slow cooling. X 100. Note rounded appearance of ferrite, probably resulting from surface tension in ferrite plates. Fig. 9—Hypoeutectoid steel overheated and quickly cooled in air. X 100. Widmanstatten structure. Ferrite has been unable to migrate to grain boundaries and is partially deposited along octahedral cleavage planes. Fig. 10—Same condition shown in Fig. 9. X 100. Here most of intersections form quadrilaterals while most of former were triangular. Both are true intersections of octahedral. Fig. 11—Well annealed hypoeutectoid steel. X 100. Note even distribution of ferrite and pearlite also small size of pearlite grains. Fig. 12—Another well annealed specimen slightly higher in carbon content. X 100.

nate laminations of iron and iron carbide. This has been called pearlite on account of the similarity of its appearance to mother of pearl. When the percentage of carbon is below the eutectoid ratio, the metal consists of iron, or ferrite and pearlite, when slowly cooled to normal temperature; when above that ratio, it consists of cementite and pearlite. Steel in the molten state is nonmagnetic and when cooling after solidifying, remains in this state until the second critical point is reached, when it again becomes magnetic. This fact, together with the marked dilatation of the metal as it passes through the third critical point has led to the conception of allotropy in iron, an allotropic form being defined as having the same chemical constitution but different physical properties, either in crystalline form, magnetic properties or thermal expansion. Thus hypoeutectoid steel above the third critical point is said to consist of a solid solution of gamma iron and carbon. Between the third and second critical points it consists of beta iron and carbon, and between the second and first critical point, of alpha iron and carbon.

As slowly cooling, molten, hypoeutectoid steel reaches the point of solidification, the molecules arrange themselves in the form of small crystals at various points throughout the molten solution. These act as nuclei for further deposition of small crystals on further cooling of the molten metal, and a solid ground mass gradually develops throughout the molten material, which finally becomes entirely solid, when the solidus is reached. Manifestly, since the axes of these small crystals are arranged in different directions, the planes of cleavage of the resulting grains, or allotrimorphic crystals, will have different directions. Since these grains have true crystalline planes of cleavage, but cannot take the crystalline form due to interference, they have been called crystalline grains and the cleavage lines are said to represent the orientation of the crystal. Also, since it is conceivable that the small crystals will continue to deposit about their various neuclei until there is no longer room for further deposition of a complete crystal between the various allotrimorphic crystals, there must remain a small amount of metal which cannot crystallize and must, therefore, remain in the amorphous condition. Rosenhain claims that this amorphous metal acts as a cement between the crystalline grains, thus accounting for the fact that rupture is nearly always transcrystalline instead of intracrystalline. The crystalline nature of the grains of steel is supported by studies of the effect of straining metals beyond their elastic limit, thus giving rise to slip along the cleavage planes. From these studies it has been shown that iron in the gamma state crystallizes in octahedral or duodecahedral forms, while beta and alpha iron take the form of cubes.

Since metal in cooling cools from the outside inward, the deposition of crystals begins on the outside and extends inwardly. Thus the crystalline growth normally would be by layers progressively, but sometimes under slow cooling conditions a pine-tree growth is set up by the linear deposition of crystals, normal to the cooling surface. This growth has been called a dendrite and such steel is said to be dendritic. Since all steels normally contain impurities, such as phosphorus, sulphur, and manganese, these impurities would be deposited in the form of impure segregates during the solidification of such a crystal growth. Phosphoritic metal is particularly prone to dendritic segregation, especially when slowly cooled.

As hypoeutectoid steel cools after solidification, no change takes

place until the critical range is reached, beginning at Ar_3. Upon passing through this point, granulation begins and the excess substance or solvent, ferrite, begins to separate out. If the cooling is sufficiently slow, the ferrite migrates to the grain boundaries, if not, it is partially deposited along the cleavage planes, the latter being the usual case with steel castings. As the metal further cools, ferrite continues to separate until Ar_1 is reached, at which point a change takes place in the austenite grain, which is now entirely transformed into pearlite. The temperatures at which these changes take place depend upon the composition of the steel and rate of cooling, certain elements causing a lowering of the critical point, and quick cooling considerably depressing it. Manganese and nickel are particularly active in depressing the lower critical point and, when present in large amounts, even depress it below the atmospheric temperature. These steels are, therefore, austenitic in character, since they never reach the lower critical point in nomal cooling.

Upon reheating steel, which is pearlitic, no change takes place until the lower critical point is reached, when an absorption of heat takes place and the pearlite is transformed into austenite. The point at which this occurs is considerably higher than the corresponding point on cooling, the difference being due to hysteresis and dependent upon the chemical composition of the material. As the temperature rises further, a gradual absorption of ferrite into the austenite grain takes place and the coarse grain structure is slowly broken up until the critical range is passed. The steel again becomes nonmagnetic on passing the second critical point upwards and, upon passing the third critical point, is again a homogeneous solid solution, providing the heating has been sufficiently slow for the completion of the reactions. The points at which these changes occur have been called Ac_1, Ac_2, Ac_3, $Ac_{2\text{-}3}$, $Ac_{1\text{-}2\text{-}3}$, $Ac_{1\text{-}2}$, Ac_3cm; "A" meaning as before a transformation point, and "c" coming from chauffage, meaning heating. If the steel is now allowed to cool slowly, a new granulation begins and on passing Ar_3, ferrite begins to separate as before along the new grain boundaries.

If the temperature to which the steel has been heated is considerably above the critical range and cooling is sufficiently slow, granulation develops rapidly and large pearlite grains develop through changes in orientation of the small crystals. On further cooling, ferrite again separates and migrates to the grain boundaries if cooling is sufficiently slow. If the rate of cooling is accelerated, however, on passing the granulating range, the ferrite cannot migrate to the grain boundaries, but is deposited along the cleavage planes of the austenite grain, giving rise to the familiar Widmanstatten structure, so common to air cooled castings which have been overheated. Since this deposition is along cleavage planes, studies of the angles of intersection have given much information regarding the system of crystallization to which the allotrimorphic crystals belong. Further slow cooling results as before in the deposition of more ferrite until the lower critical point is reached, when austenite is again changed into pearlite.

Up to this time, metal cooling slowly from above the critical range has been considered. If the rate of cooling is accelerated by quenching, time is not given for the completion of the deposition of the excess ferrite and this remains dissolved in the austenite grain in varying proportions, depending upon the rapidity of the fall in temperature. If the cooling has been very rapid, most of the ferrite is in solution and

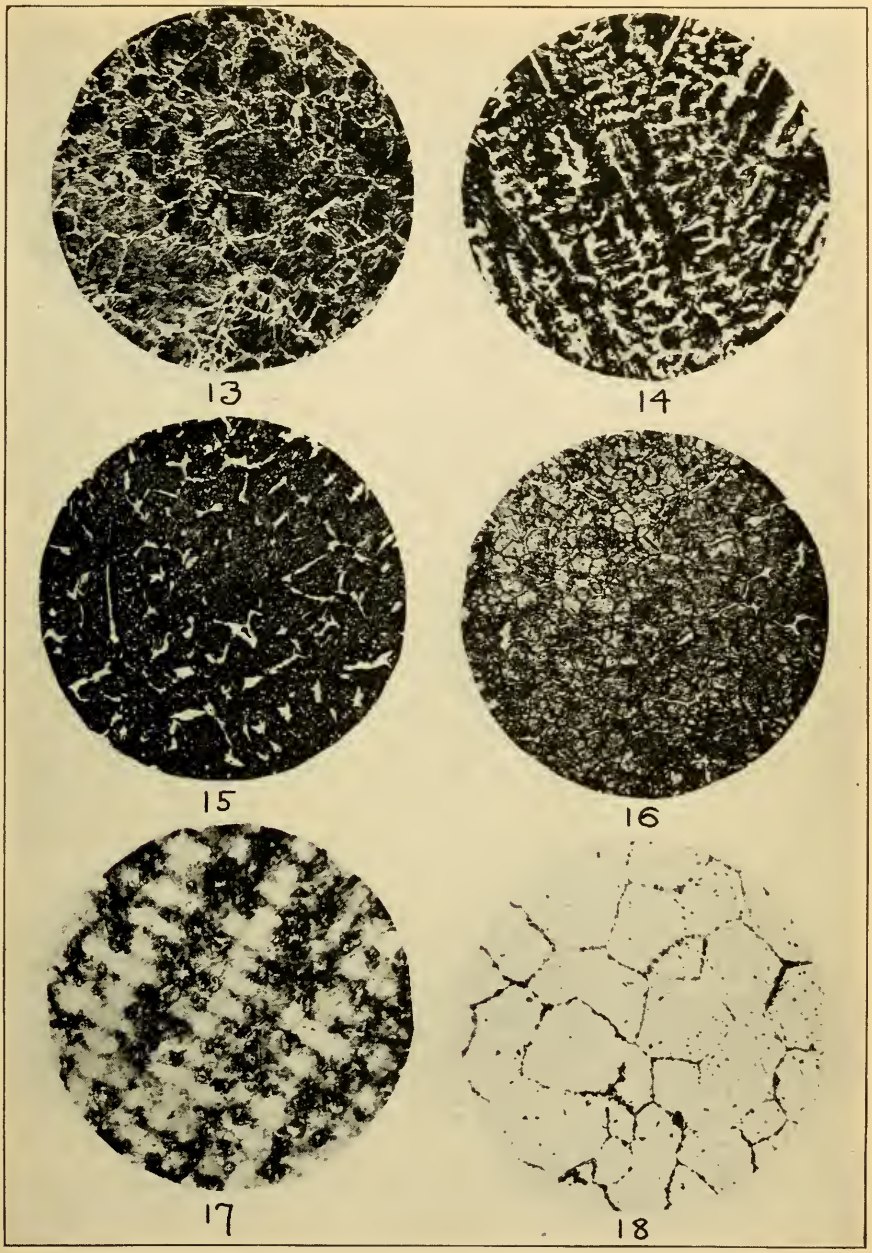

Fig. 13—Structure developed by quenching hypoeutectoid steel. X 100. Note thin ferrite lines surrounding sorbitic grains. Fig. 14—Hard iron as cast. X 100. Shows dendritic structure. Hypereutectoid material, the excess substance being cementite. Fig. 15—Hard iron heated partially through critical range and quenched. X 100. Shows partial absorption of cementite. Fig. 16—Hard iron heated to near solidus and quenched. X 100. Note almost complete absorption of cementite and martensitic nature of material. Fig. 17—Dendritic structure resulting from linear deposition of crystals normal to cooling surface. X 100. This specimen was highly phosphoritic. Fig. 18—Same material as shown in Fig. 17, but properly treated to eliminate dendritic structure. X 100.

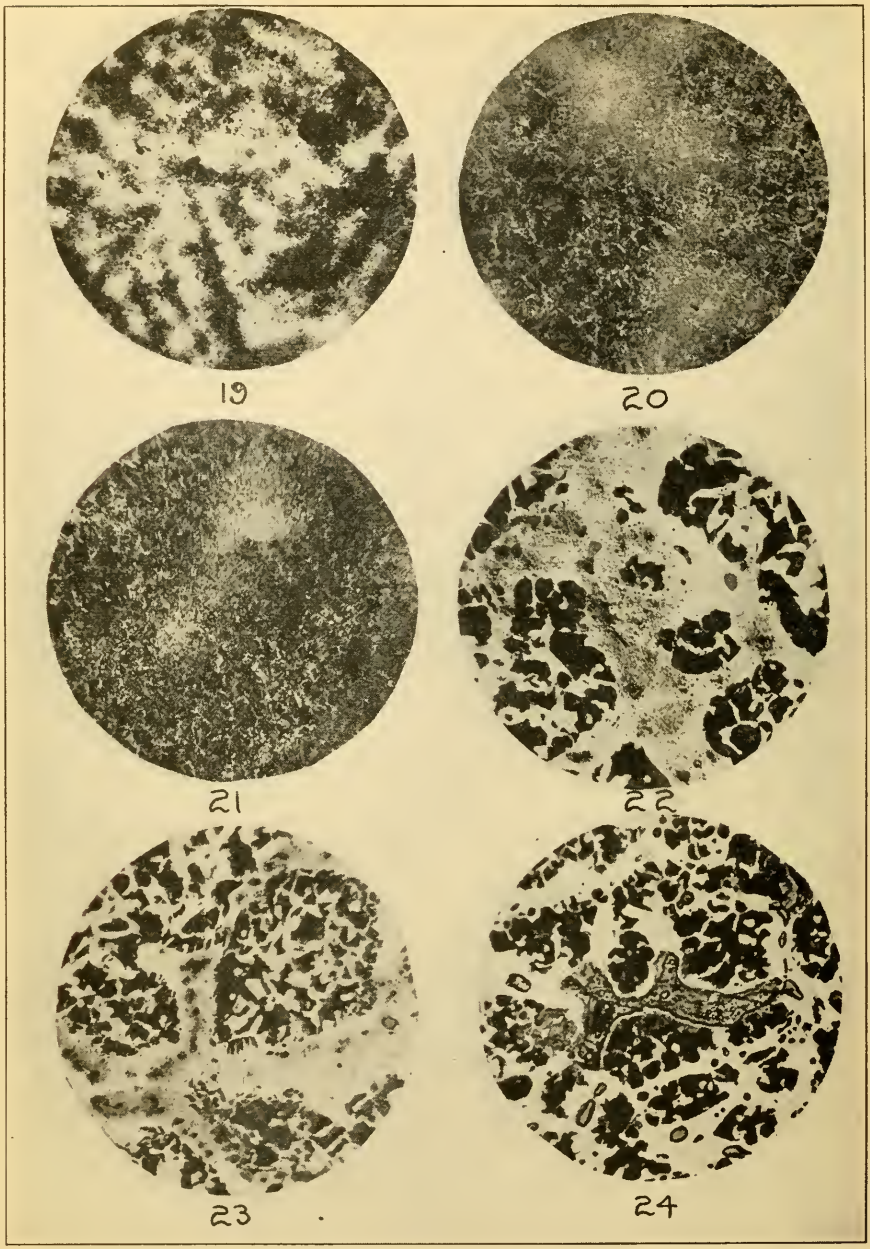

Fig. 19—Radial dendrites developed normal to a curved surface. X 100. Fig. 20—Ghosts. Specimen has been quenched but previous heating has not completely broken up dendritic structure which appears as faint, hazy spots. X 100. Fig. 21—More ghosts. These have been developed in a region containing cavities due to occluded gases. X 100. Fig. 22—Ferrite plating caused by presence of sonims. Annealing has not caused the ferrite plates to go into solution. X 100. Fig. 23—More sonims surrounded by ferrite plates. X 100. Slag inclusions have formed nuclei for deposition of ferrite. Fig. 24—Sulphides and silicates of manganese surrounded by ferrite envelopes. X 100.

the metal is hard and brittle. In this condition it is said to be martensitic. If martensitic material is reheated slightly, part of the ferrite is liberated and the hardness diminishes. The metal then becomes troostitic in character. Still further heating liberates more ferrite and it is found that the austenite grain has become amorphous in structure. This is the sorbitic condition and is the most desirable, where high tenacity combined with ductility is desired. Further heating up to the critical point again leaves the steel in the pearlitic condition, which is the regular annealed state and gives the highest ductility.

The annealing of steel castings for proper physical properties is complicated by the fact that no work is done on the plastic material, which would assist in the breaking up of the crystalline grain structure, which must be entirely eliminated by heat treatment. The result is that castings require a higher temperature and longer time to accomplish this. Thus a proper anneal would require that the castings be slowly heated to a point considerably above the critical range and held long enough to insure the penetration of the heat to the center. This, of course, is regulated by the thickness of the section, and since most castings have variable sections, heating must be regulated partly by the thinnest section, which will be put under strain when a single anneal is desired. By proper regulation of the temperature-time functions excellent results can be accomplished with a single anneal, but where the sections are varied, it is obvious that the lighter sections become overtreated before proper treatment has been accomplished in the heavier. In cases of this kind the proper course is to give a double anneal, first heating to a fairly high point to refine properly the heavy section, and then cooling below the lower critical point and reheating to a lower temperature to break up the secondary structure set up in the thin sections. In anneals of this type, a fairly rapid cooling through the granulating range, followed by slow cooling past the lower critical point, is advantageous on account of the finer grain structure generated.

Thus far only pure carbon steel has been considered in our discussion. However, all steel contains to a more or less degree certain impurities which are inherent to the method of manufacture. These impurities consist of gases, which remain dissolved in the solid metal, called occluded gases; particles of slag from the bath or refractories; and reaction products of the deoxidizers used in the bath and ladle, called sonims.

When steel is in the molten state, it has a great solvent power for the gaseous products of the furnace reactions and thus contains quantities of carbon monoxide, nitrogen, oxygen, and some hydrogen in solution. When the steel solidifies, its solvent power decreases and these gases when present to marked degree, are liberated to a certain extent, forming cavities or blow holes in the pasty metal. Certain elements, such as manganese, aluminum, silicon, and titanium, when added to steel, either react with these gases to form compounds which pass away into the slag, or increase the solubility of the steel for these gases. When present in sufficient quantity to form considerable blowiness, these gases seem to exert a local depressing effect upon the critical point of the steel, thus causing overtreatment of these areas when given the usual heat treatment. This results both through their depressing effect and the cutting down of the area of the section. The presence of these gases in excess leads to excessive shrinkage with all of its evils due to piping and

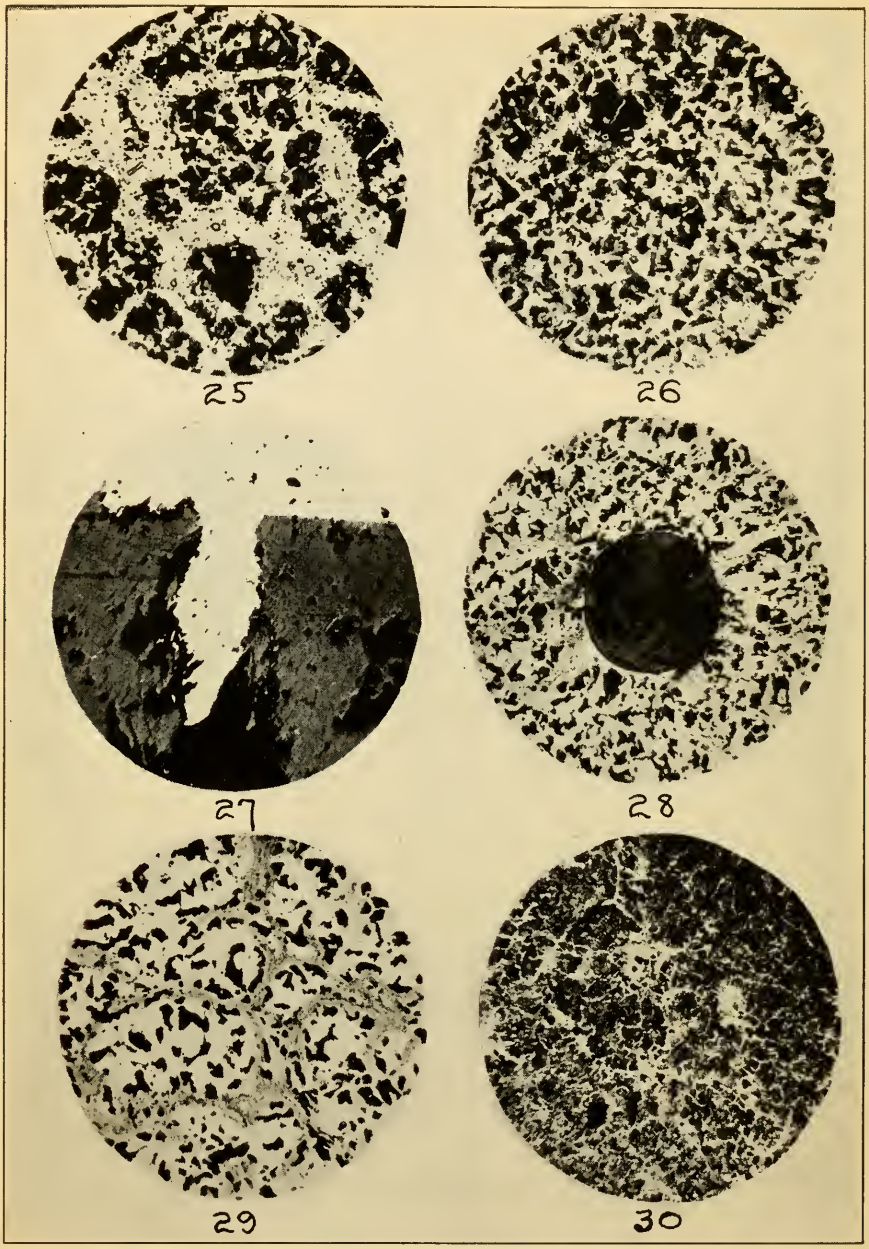

Fig. 25—Persistent ferrite segregation caused by numerous small slag particles. X 100. Fig. 26—Same material as in Fig. 25 but containing few sonims. X 100. Note even distribution of ferrite and pearlite. Fig. 27—Silicate of manganese inclusion at edge of cavity. Unetched X 100. Note slate gray color of inclusion. Fig. 28—Silicate of manganese inclusion. X 100. Metal has solidified about semimolten material causing it to become spherical in shape. Fig. 29—Slag inclusions along grain boundaries. X 100. Typical of ferrous sulphide inclusions. Fig. 30—Quenched material containing sonims. X 100. Note persistent nature of ferrite envelopes which show as thin white envelopes surrounding sonims in sorbitic background.

cracking, where heavy and light sections join. The steel is then generally spoken of as oxidized metal. It is found generally that where excessive shrinkage occurs, small hair-like cracks are developed radiating outward from the pipe. With proper annealing these are sometimes eliminated, but if the pipe has an opening to the atmosphere, which occurs in most cases, the surfaces of these cracks become oxidized and they cannot be eliminated. Many times it is found that the area immediately surrounding a pipe is decarbonized, due to the action of the oxygen of the air drawn into the pipe upon the carbon in this area. These cracks and decarbonized areas have a localized weakened condition, and while benefited by heat treatment, are never completely eliminated. This condition is properly a furnace and foundry condition and should be eliminated there.

The slag inclusions and reaction products of the "deoxidizers" have been called sonims, the word being derived from the expression "solid nonmetallic impurities". The churning action of the bath when boiling and of the metal when running into the ladle, causes a mixing of small globules of the slag and reaction products with the steel. These consist of sulphide of manganese, probably containing some ferrous sulphide, iron silicates, manganese silicate, and, where aluminum is used as a deoxidizer, of aluminum oxide.

If the metal is not sufficiently fluid, or if sufficient time is not allowed, these inclusions cannot rise to the surface with the main body of the slag, but remain suspended in the molten metal as semisolids, due to their higher melting points, and are carried with the stream of metal into the castings, where they form solid inclusions in the metallic section. These inclusions have very little strength in themselves, and thus act much as cavities in reducing the strength of the section. However, the role played by these inclusions does not stop with the cutting down of the sectional area, but it has been demonstrated that they probably promote a segregation of ferrite about themselves during the cooling from above and through Ar_3. These inclusions are always found surrounded by ferrite, even when located inside pearlite grains. These ferrite segregations form a ductile, weak spot and give rise to the faint, hazy appearing spots called "ghosts" appearing upon a polished and etched specimen, especially when complicated by dendritic structure, caused by phosphorus segregation. A dendritic structure resulting from phosphorus segregation can be eliminated by prolonged exposure to a high temperature, followed by quick cooling, preferably quenching.

On the other hand, ferrite segregation caused by sonims is very persistent and, while partially absorbed by prolonged heating to a high temperature, still shows a ferrite envelope surrounding the sonims, even in quenched specimens. The sonims, likewise, are unaffected in shape by heat treatment, and since they probably belong to the same system of crystallization as alpha iron, offer good nuclei for segregation of ferrite. Some experiments by Mahin have led him to think that ferrite segregation is promoted by a partial solution of the inclusion in the surrounding metal, thus hastening the rejection of the ferrite through the law of solubility. Manganese sulphide and iron sulphide are frequently found where shrinkage cracks occur and probably promote the formation of shrinkage cracks, due to the formation of intracrystalline films.

Steel castings often show slight defects which are removed by weld-

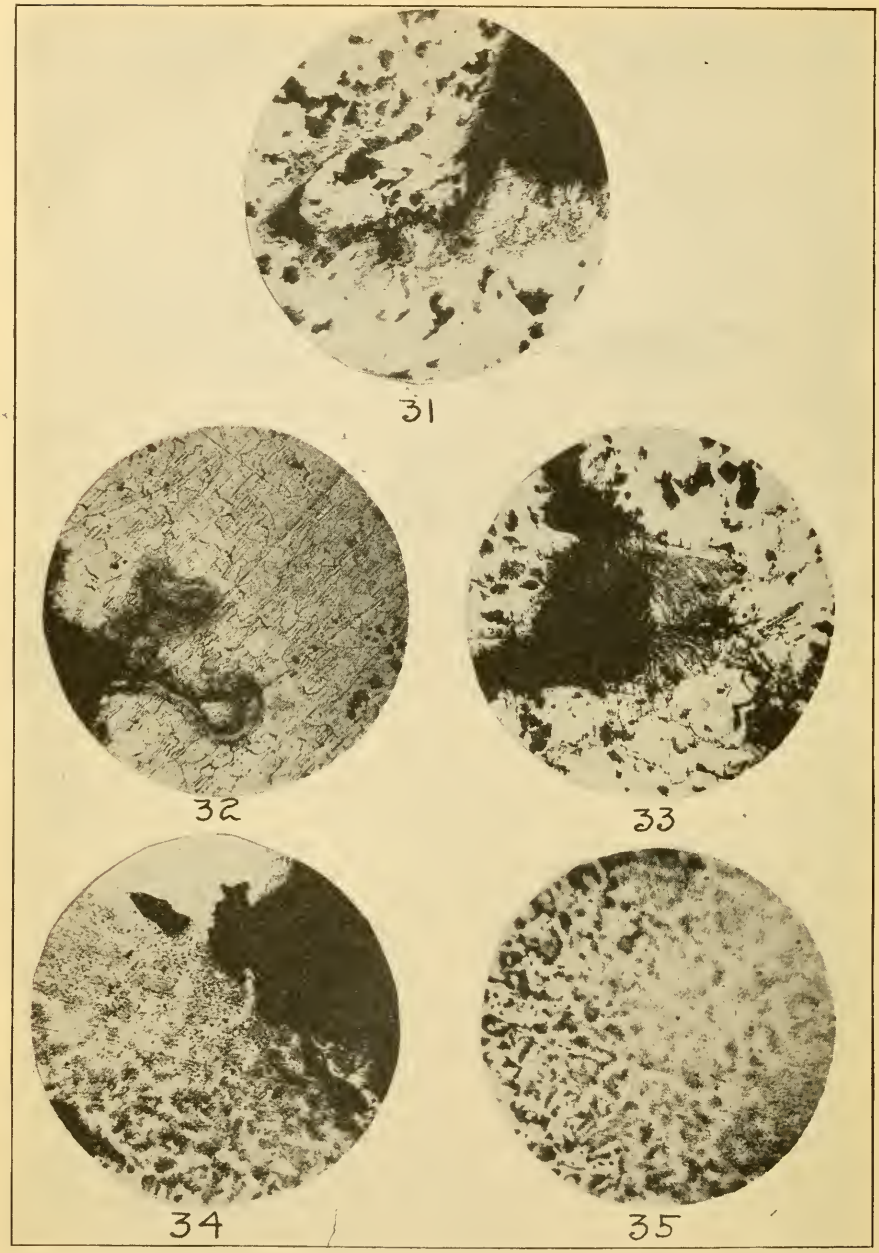

Fig. 31—Junction of a "scab" to main body of metal. X 100. Note crack extending into main body from point of junction. This acts much as a notch when put under stress. Fig. 32—Shrinkage cavity surrounded by a decarbonized area. X 100. Air drawn into cavity has oxidized carbon in surrounding material. Fig. 33—Area adjoining a shrinkage cavity showing fine hair-like cracks extending outward from cavity. X 100. Stress applied to material has caused slip along one of these cracks with resultant rupture and distortion of moving grain. Fig. 34—Improperly made weld showing cavity containing foreign inclusions. X 40. Also note gradation of structure from carbonless iron to overheated structure of normal steel. Fig. 35—Properly made weld. X 40. Note smoothness of shading from carbonless iron to normal steel. Overheated structure shown leaves no doubt that welded castings should be reannealed.

ing. These are generally in the nature of small cavities or cracks. The welding is accomplished usually by causing the metal surrounding the defect to assume the liquid state, through the use of the electric arc or oxyacetylene torch, and flowing into it sufficient low carbon rod to fill the defect. Manifestly, the steel in this region is in the coarse, crystalline state of unannealed castings and should be refined by annealing. In cases of this kind an anneal which would increase the notch toughness of the material should be beneficial. Fairly quick cooling, so as to prevent the complete formation of lamellar pearlite, increase notch toughness, which is greatest when the steel is sorbitic.

In concluding it may be said that steel castings can be refined by heat treatment to possess physical characteristics comparable to forgings, but longer and more drastic treatment is required. Defects inherent to cast steel are more pronounced in castings due to lack of mechanical working. Foreign inclusions have a marked influence upon the strength of the steel casting, due to their segregating influence upon ferrite. The rate of cooling of castings after pouring exerts an influence upon the size of the crystalline grains and especially upon material which has a tendency to formation of dendrites. Dendrites can be eliminated by heat treatment, but require drastic treatment. Shrinkage should be eliminated in the furnace and foundry practice. Welded castings should be reannealed to remove strains and to properly refine the grain.

THERMAL AND PHYSICAL CHANGES ACCOMPANYING THE HEATING OF HARDENED CARBON STEELS

By Howard Scott and H. Gretchen Movius

WIDESPREAD interest which has been expressed recently in the properties of steel in the "blue-heat" range and in the subject of "temper brittleness" makes it highly desirable to study in detail the transformations in steel below the A_1 change. In a previous paper[1] the authors have pointed out certain thermal characteristics of the magnetic change in cementite as observed in annealed steels by means of thermal analysis. In this paper the subject under investigation is the thermal change observed in hardened steels on heating below Ac_1.

Outside of the possible bearing of such information on the low-temperature properties mentioned, there remains the desirability of establishing fundamental characteristics of steel. The one in question is of particular value in that it may furnish a practical basis for defining the natural boundary between martensite and the troostite of tempering, which from present information is very indefinite.

A survey of the changes in some of the physical properties of carbon steels on tempering would, on account of certain inconsistencies, lead one to doubt the existence of a sharp demarcation between the constituents—martensite and troostite. Heating curves of hardened steels, however, have shown a well-marked heat evolution ending around 300 degrees Cent. Such heat evolution would be expected from the usual conception of the formation of martensite; namely, that one or more of the transformations occurring on slow cooling are suppressed by quenching. The consummation of the suppressed transformation, or transformations, is a manifestation of the completion of the constitutional change, and, therefore, evidence of a boundary between two constituents, presumably martensite and troostite. Whether the end of this heat evolution should be used to define those constituents the future will decide; the present work seeks only to establish its nature in a variety of carbon steels and its relation to accompanying changes in some of the physical properties.

In the literature some work has appeared on this heat evolution in hardened carbon steels. Osmond [2] and Maurer[2] have given inverse-rate heating curves; Heyn and Bauer[3] and Portevin[3] have given differential curves showing the phenomenon.

The temperature values for the transformation are somewhat higher than those obtained here. In general, the curve inflections are neither prominent enough nor the statement of operating details sufficient to allow of a precise definition of the transformation characteristics. Also the effect of important variables has not been determined. This phenomenon has been observed also by continuous measurement of the changes in some physical properties on heating. Grenet[4] detected an inflection in the expansion and electric-resistance curves of a high-carbon steel, Chevenard[5] in expansion curves, and Honda[6] in magnetic-induc-

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1 Chemical and Metallurgical Engineering, **22**, p. 1069; June 9, 1920.
2 Osmond, J. Iron and Steel Inst., p. 38; No. 1, 1890. Maurer, Rev. de Met., **5**, p. 711; 1908.
3 Heyn and Bauer, J. Iron and Steel Inst., **79**, p. 109; 1909. Portevin, de Met., **13**, p. 9; 1916.
4 Grenet, Rev. de Met., **1**, p. 353; 1904.
5 Chevenard, Rev. de Met., **14**, p. 610; 1917.
6 Honda, Sci. Reports Tohoku Imp. Univ., **6**, p. 149; 1917.

tion curves. The magnetic curves are the only ones which seem to follow closely the progress of the heat change. Brush[7] has made extensive observations on the heat evolution at ordinary temperatures in recently hardened steels. He noted a heat evolution, greatest immediately after

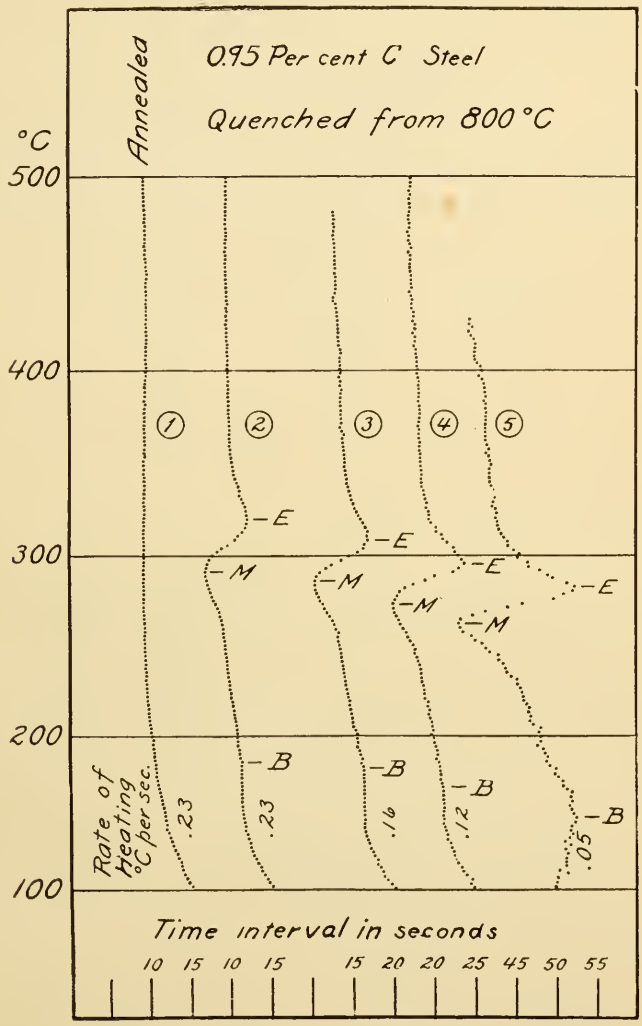

Fig. 1—Inverse rate heating curves of hardened steel, showing effect of rate of heating on Ac

hardening, gradually diminishing in rate with time and becoming imperceptible after several weeks. The physical changes accompanying this spontaneous evolution were very small in comparison with those accompanying even slight tempering.

While the present research is confined to carbon steels because of

7 Brush, Bull. A. I. M. M. E. No. 153, p. 2389; 1919.

their fundamental importance, it is being extended to alloy steels in order to obtain further light on the effect and function of the alloying elements.

The inverse-rate method of obtaining thermal curves has been used at the Bureau of Standards as the most effective and satisfactory method for studying the transformations in steel. Used in connection with the

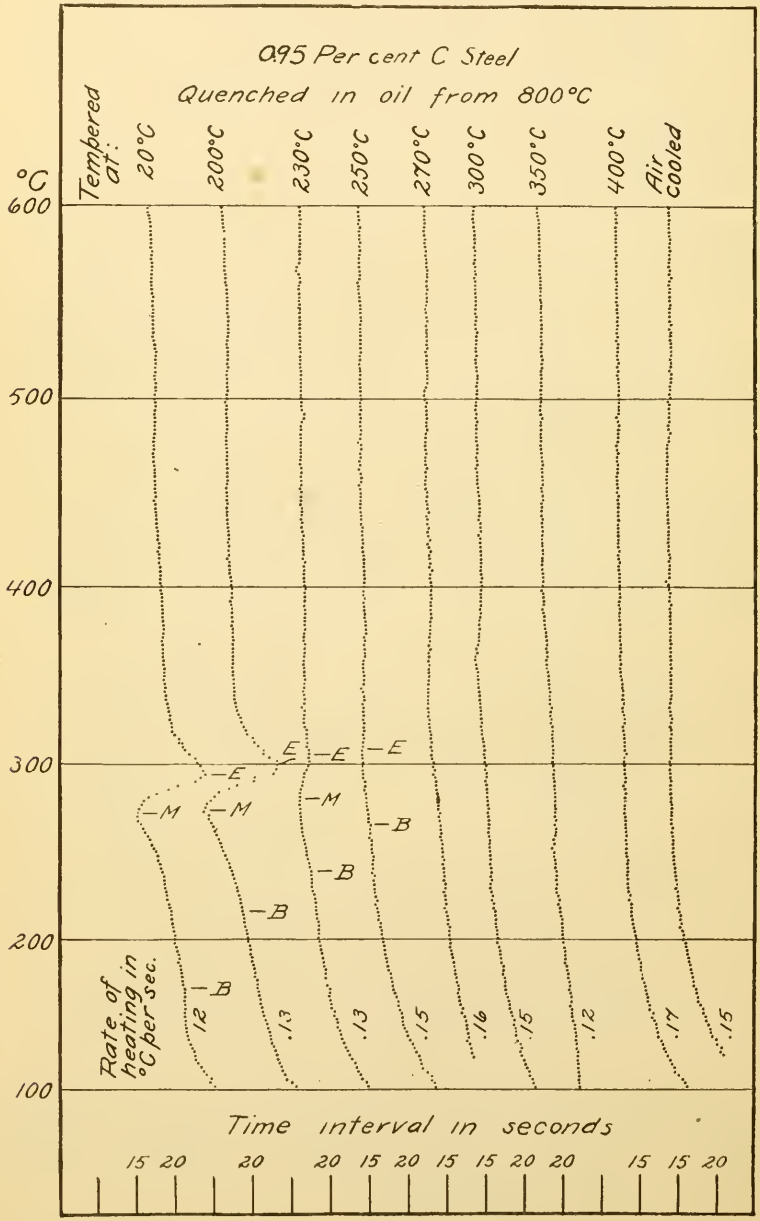

Fig. 2—Inverse rate heating curves of hardened steel, showing effect of previous tempering for 30 minutes on Ac_1

apparatus already described[8] excellent curves can be obtained at the low temperatures where the heat evolution under examination is found. The details of mounting size of sample, and operation are given in the above reference. A temperature interval corresponding to 20 microvolts on a platinum, platinum-rhodium thermocouple was used in this investigation.

The materials studied were seven steels of the compositions given in Table I. Heating for quenching, as noted on the curves and in the tabulated results, was carried out on the prepared samples by introduction into an electrically heated alundum-tube furnace wound with resistance wire. Charcoal was present to reduce oxidation, and a platinum, platinum-rhodium thermocouple was used for the measurement of temperature. In tempering, the specimen was heated 30 minutes in an oil or

Table I

RESULTS OF CHEMICAL ANALYSES OF STEELS INVESTIGATED

Carbon Per cent	Manganese Per cent	Silicon Per cent	Phosphorus Per cent	Sulphur Per cent
0.40	....	0.01	....	....
.44	1.00	.02	....	....
a .46	.35	.06	0.02	0.05
a .73	.38	.01	.04	.05
.95	.22	.24	.02	.01
1.01	....	.01	....	.005
1.94	....	.01	....	.005

a Furnished by courtesy of Carnegie Steel Co.

nitrate bath, as required by the temperature. Temperatures below 300 degrees Cent. were measured with a mercury thermometer.

All samples of the quenched 0.95 per cent carbon steel not receiving subsequent tempering were run within from one to three days after quenching. All the other steels not tempered were run within from 6 to 16 days after treatment, excepting the 1.01 per cent carbon and 1.94 per cent carbon steels, which were run the day following treatment.

The principal phenomenon under consideration here, the heat evolution on heating hardened carbon steels, will be designated as "Ac_t," a notation used by one of the authors[9] for the same phenomenon in a high-alloy steel.

The thermal curves, taken to show the effect of several variables on the transformation Ac_t, are shown in Figs. 1, 2, 3, 4, and 5. For the reduction of the thermal-curve data to tabular form, the temperatures of the principal curve bends caused by the Ac_t transformation were taken as denoted on the curves by B, M, and E, beginning, maximum, and end, respectively. The rate of heating given is that just before the beginning of the transformation. The values in the column of Table II marked "Intensity" represent the difference in seconds between the time at the maximum and at the end of Ac_t, except in the case of the austenitic steel, where they represent temperature drop.

The temperature of the maximum of Ac_1, maximum temperature before decalescence when that phenomenon was observed, is also given, but the heating curves are not plotted to show Ac_1, in order to avoid excessive reduction of the curves on reproduction.

Rate of heating has a considerable effect on the temperature and form of Ac_t for the comparatively fast rates required by thermal analysis,

8 Scott and Freeman, Bull. A. I. M. M. E. No. 152, p. 1429; 1919. Also B.S. Sci. Papers, No. 348.
9 Scott, Bull, A.I.M.M.E. No. 146, p. 157; Feb., 1919. Also B.S.Sci. Papers, No. 335.

as may be seen from the curves of Fig. 1, which were taken on the 0.95 per cent carbon steel. The principal data taken from these curves are plotted with rate of heating as the abscissas, in Fig. 6. It will be noted from this figure that the temperature characteristics of Ac_t for zero

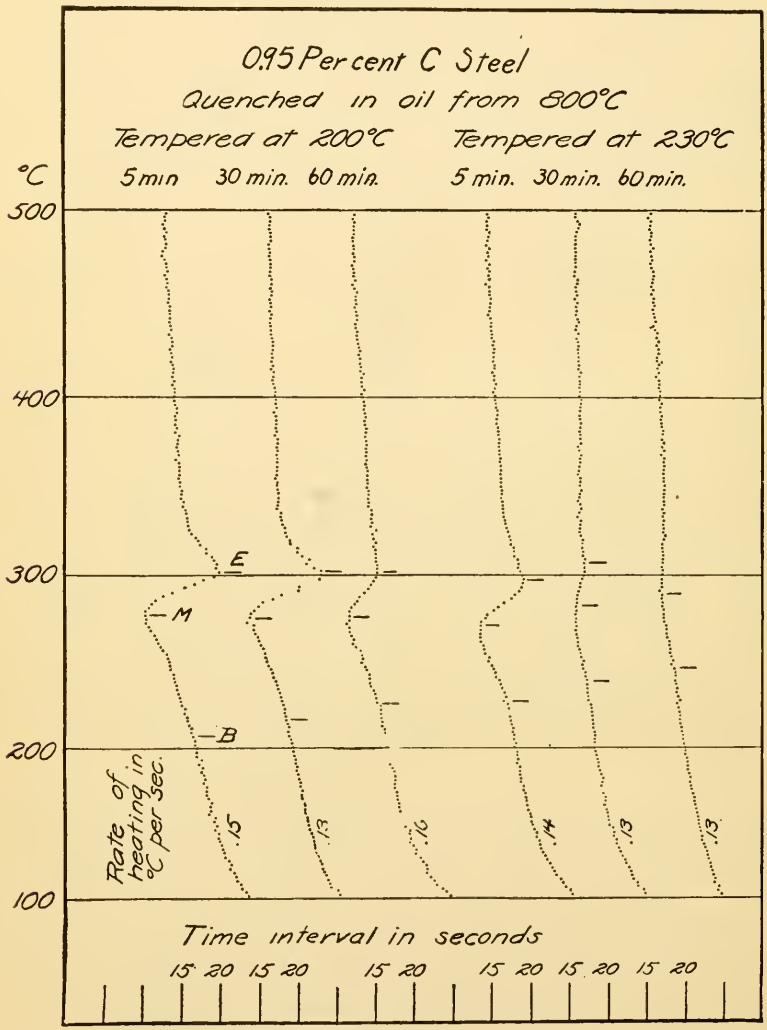

Fig. 3—Inverse rate heating curves, showing effect of duration of previous tempering on Ac_t

rate are 155, 250, and 260 degrees Cent., respectively for the beginning, maximum, and end of the transformation. This appears to represent the progress of the transformation for a tempering time approximating nomal tempering conditions, probably about 30 minutes. From the

sharpness of the beginning of the transformation it would appear that the quenched steel is the equivalent of a steel instantaneously cooled and then drawn in the neighborhood of 150 degrees Cent. Fig. 6 illustrates this interesting point: That for the size of specimen used in this

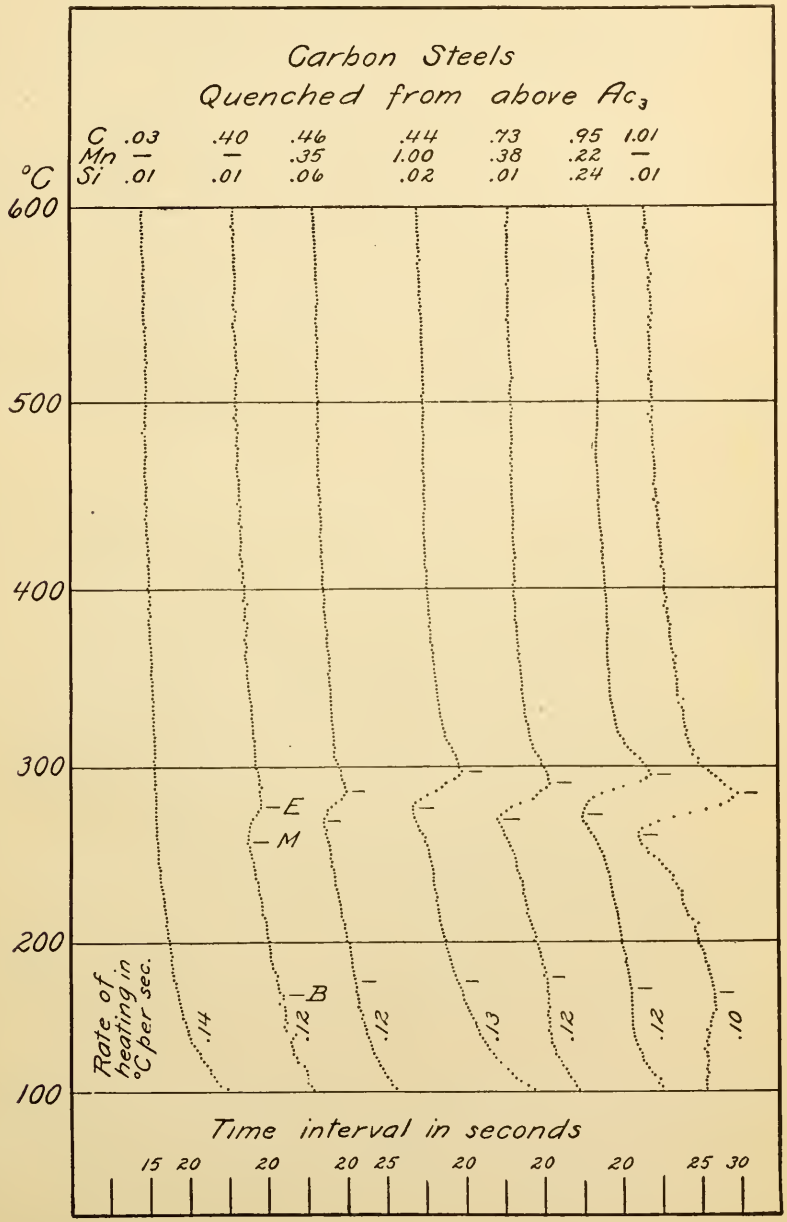

Fig. 4—Inverse rate heating curves of quenched steel, showing effect of composition

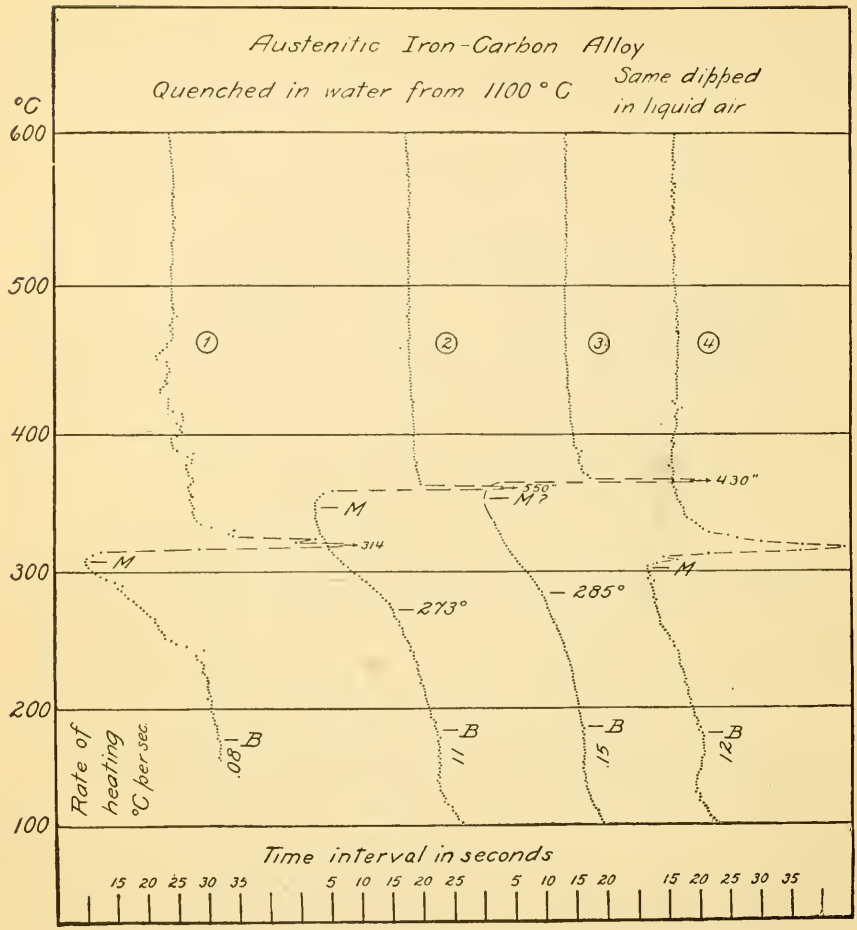

Fig. 5.—Inverse rate heating curves of austenitic iron-carbon alloy (1.94 per cent carbon)

case there is no appreciable difference between thermal characteristics of an oil-quenched and of a water-quenched specimen.

The heating curves represent the progress of tempering for a necessarily very short time at any temperature in the Ac_t range. To show the effect of holding for a definite time at several tempering temperatures on the characteristics of Ac_t, heating curves were taken on specimens of the 0.95 per cent carbon steel quenched in oil from 800 degrees Cent. and tempered 30 minutes at the temperatures given in Fig. 2 and Table II.

From a consideration of these data it may be seen: (1) That the beginning of Ac_t is from 10 to 17 degrees Cent. higher than the tempering temperature when that is above 200 degrees Cent.; (2) that the transformation is completed at a temperature between 250 and 270 degrees Cent; and (3) that for each temperature up to 250 degrees Cent. there is a definite and characteristic form of curve. The estimated temperature of the end of Ac_t for zero rate or 260 degrees Cent. is, therefore,

from (2) in practical agreement with the end of the transformation for a tempering period of 30 minutes. From (1) and (3) it is evident that the heating curves might be used to estimate the previous tempering temperature within certain limits.

It may be of interest to note that, for a tempering temperature of

Table II

THERMAL CHARACTERISTICS OF HARDENED CARBON STEELS

Composition			Heat treatment				Ac. temperature					
Carbon	Manganese	Silicon	Quenching temperature	Quenching medium	Tempering temperature	Time at tempering temperature	Rate of heating	Beginning	Maximum	End	Intensity of heat evolution	AC1 maximum
Per cent	Per cent	Per cent	Degrees Cent.		Degrees Cent.	Minutes	Degrees Cent. per sec.	Degrees Cent.	Degrees Cent.	Degrees Cent.	Seconds	Degrees Cent.
							(1) Effect of heating at different rates					
0.95	0.22	0.24	800	Water			0.23	183	290	319	5	735
			800	do			.16	178	285	308	7	.....
			800	do			.05	162	261	282	14	.....
			800	Oil			.22	167	273	295	8.5	733
			(a)				.23	.....	.....	.....	0	736
							(2) Effect of tempering at different temperatures					
.95	.22	.24	800	Oil			0.12	167	273	295	8.5	733
			800	do	200	30	.13	215	275	300	9.0	733
			800	do	230	30	.13	240	282	307	1.5	733
			800	do	250	30	.15	267	.....	310	0.5	734
			800	do	270	30	.16	.....	.....	.....	0	734
			800	do	300	30	.15	.....	.....	.....	0	733
			800	do	350	30	.12	.....	.....	.....	0	733
			800	do	400	30	.17	.....	.....	.....	0	733
			(b)	do			.15	.....	.....	.....	0	735
							(3) Effect of tempering for different periods of time					
.95	.22	.24	800	Oil	200	5	0.15	204	276	300	9	.....
			800	do	200	30	.13	215	275	300	9	.....
			800	do	200	60	.16	224	273	300	4	.....
			800	do	230	5	.14	224	271	296	5.5	.....
			800	do	230	30	.13	240	282	307	1.5	.....
			800	do	230	60	.13	244	289	350	0.5	.....
							(4) Results for different compositions					
.40	.....	.01	900	Water			0.12	167	259	278	2	731
.46	.35	.06	900	do			.12	174	270	286	3	731
.44	1.00	.02	900	Oil			.13	174	276	297	6	727
.73	.38	.01	900	Water			.12	175	271	292	7	731
.95	.22	.24	800	Oil			.12	167	273	295	8.5	733
1.01	.....	.01	800	Water			.10	167	261	284	13	728
							(5) Results for austenitic structure					
											C. Temp. drop	
1.94	.....	0.01	1,100	Water			0.08	174	308	319	2	.....
			1,100	do			.11	182	347	361	24	.....
			1,100	do			.15	184	353	366	.....	731
			1,100	do	180	30	.12	179	302	317	0	.....

a Annealed. *b* Air cooled.

270 degrees Cent. and 300 degrees Cent., Fig. 2, there is a slight deflection of the curves to the right, indicating an absorption of heat over the range of about 350 to 450 degrees Cent., which is in conformity with the observations of Heyn and Bauer[10] under similar conditions.

It has long been recognized that the time of holding at a tempering

10 See footnote 3.

temperature has a very considerable effect on the resulting physical properties, and it is even held that a long time at a low temperature is equivalent to a short time at a higher temperature. The thermal curves of steels tempered for different lengths of time in the Ac_t range should, therefore, throw some light on the validity of this much discussed proposition.

In Fig. 3 heating curves are given to show the effect of maintaining a steel for different lengths of time at the tempering temperature. The

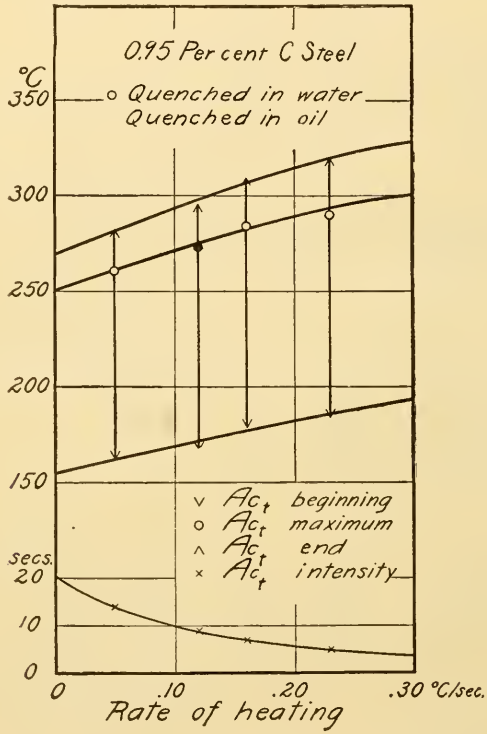

Fig. 6—Effect of rate of heating on temperature and intensity of heat evolution of 0.95 per cent carbon steel

0.95 per cent carbon steel, hardened by being quenched in oil from 800 degrees Cent., was used. Specimens were maintained for 5, 30 and 60 minutes at each of the two tempering temperatures, 200 and 230 degrees Cent., chosen because they represent temperatures at which tempering is well in progress, but not to such an extent as to eliminate the thermal effect.

It may be noted from these curves and the compiled data of Table II: (1) That the beginning of Ac_t is higher for a long than for a short exposure at the tempering temperature; (2) that the intensity of the transformation is less for a long tempering period than for a shorter one; and (3) that the rate of progress of the transformation is greater at the higher tempering temperature than at the lower one.

From (1) and (2) it is apparent that time has a decided effect on

the transformation characteristics. The third conclusion is evident from the fact that at 200 degrees Cent. an exposure of 60 minutes is necessary to reduce markedly the intensity of Ac_1, while at a temperature only 30 degrees Cent. higher the intensity is much more strongly reduced by a 30-minute exposure. This is in agreement with the tempering experi-

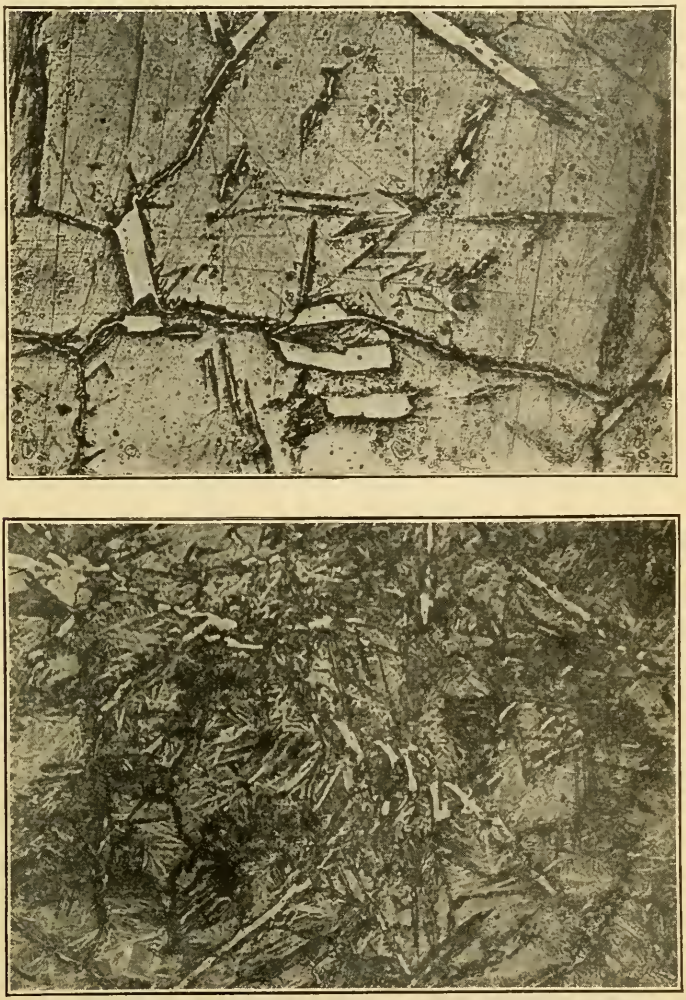

Fig. 7—Microstructure of 1.94 per cent carbon steel quenched in water from 1100 degrees Cent. Etched with 2 per cent alcoholic nitric acid. (Above) As quenched. x 500. (Below) Same as above but dipped in liquid air 30 minutes. x 500

ments of Barus and Strouhal,[11] whose measurements of electrical resistance and thermal emf show the rate of transformation to be much greater at the higher tempering temperatures in the Ac_1 range. This indicates further that the tempering time of 30 minutes used in the preceding section represents actual equilibrium or zero-rate conditions at the tem-

11 Barus and Strouhal, Bull. U. S. Geological Survey, No. 14; 1885.

perature of the end of Ac_1, though, of course, not at lower temperatures.

It may be inferred from the nearly identical characteristics of Ac_t following tempering for 60 minutes at 200 degrees Cent. and 5 minutes at a temperature 30 degrees Cent. higher, that these two treatments produce the same structural condition, but, because the rate of transformation changes with temperature, it does not follow that this particular relation holds quantitatively for any other temperatures in the Ac_t range.

In general, however, the effect of time may be regarded as equiva-

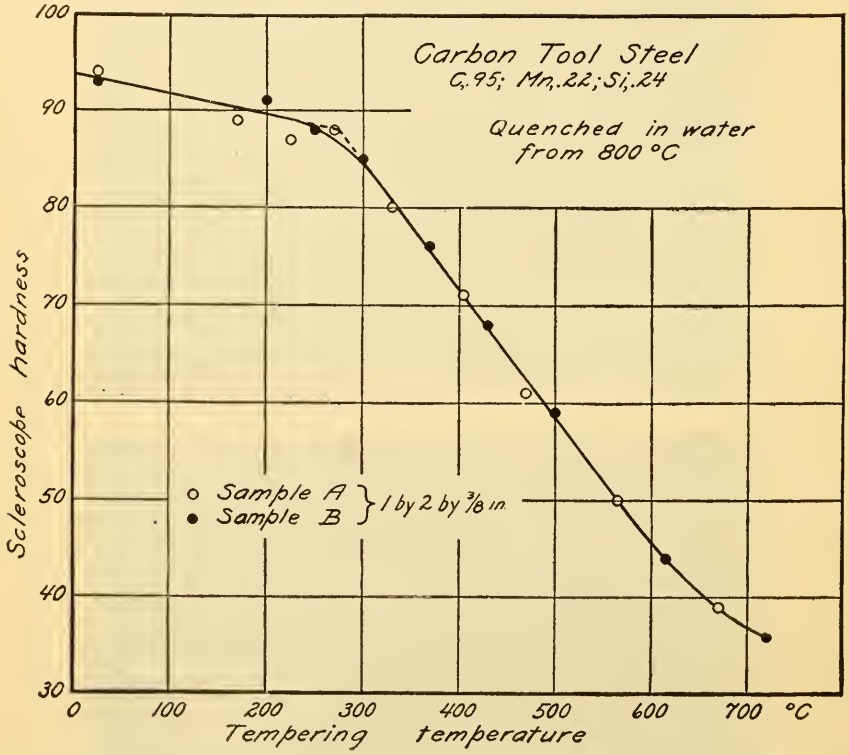

Fig. 8—Effect of tempering temperatures on scleroscope hardness of 0.95 per cent carbon steel

lent to that of temperature within limits as far as the characteristics of Ac_t are a criterion of the constitutional changes in the steel.

For the sake of comparison of the several martensitic steels investigated, the temperature values of Ac_t taken from Table II have been given a small correction on the basis of Fig. 6 to reduce them to a constant rate of heating of 0.10 degrees Cent. per second; these values are given in Table III. By comparing the synthetic steels in the first group, low in manganese, or the commercial steels in the second group, containing 0.20 to 0.40 per cent manganese, with respect to the variable carbon, one may see that the maximum and end of Ac_t are somewhat higher for the higher carbon contents and that the transformation intensity is approximately proportional to the carbon content.

The effect of an increase of carbon on the heat evolution is to augment correspondingly the rate at a given stage in the progress of the

transformation for a given furnace rate. This increase in rate from the effect noted on rate of heating, will raise the temperature of the maximum and end of Ac_t. The increase in temperature of the maximum and end of Ac_t with increasing carbon, being small, is probably due entirely to the augmented rate of heating. This factor being ineffective for very slow or zero rate of heating, it may be stated that, for this case, the carbon does not materially affect the maximum and end of Ac_t. Likewise, the rate at the beginning is unaffected by the subsequent heat evolution, so that the constancy of that point verifies the conclusion that the temperature of Ac_t is practically independent of carbon content under conditions which render the effect of intensity impotent.

From Table III it may be of interest to note further that Ac_t is slightly higher in the commercial than in the pure synthetic steels of the same carbon content, and that the characteristics of Ac_t for the steel

Table III

TRANSFORMATION CHARACTERISTICS OF MARTENSITIC STEELS FOR RATE OF HEATING OF 0.10 DEGREES CENT. PER SECOND

Carbon	Manganese	Silicon	Ac. temperature Beginning	Ac. temperature Maximum	Ac. temperature End	Intensity
			Synthetic Steels			
Per cent	Per cent	Per cent	Degrees Cent.	Degrees Cent.	Degrees Cent.	Seconds
0.40	.....	0.01	165	255	274	2
1.01	.....	.01	167	261	284	13
*a*1.94	.....	.01	177	298	313	32
			Commercial Steels			
.46	.35	.06	172	266	282	3
.73	.38	.01	173	267	288	7
.95	.22	.24	165	269	291	8.5
			Synthetic 1 Per Cent Mn Steel			
.44	1.00	.02	170	270	291	6

a Martensitic by immersion in liquid air; curve 4, Fig. 5.

containing 0.73 per cent carbon and 0.38 per cent manganese are practically identical with those for the steel containing 0.44 per cent carbon and 1.0 per cent manganese.

For obtaining the data presented in preceding examples, the material used was a martensitic steel, but it was believed to be of some interest to study also the thermal changes accompanying the decomposition of an austenitic matrix in a carbon steel. With this in mind, a steel of 1.94 per cent carbon content was quenched in water, the resulting structure being uniformly austenitic as shown in Fig. *7a*.

The curves taken on specimens given such treatment are shown in Fig. 5, curves 1, 2, and 3, and the data taken from them, are shown in Table II. The transformation observed was very intense, and in one case, Fig. 5, curve 3, the heating advanced so rapidly that the operator could not follow it. In every case the heat evolution increased the specimen temperature at the end of the transformation so that it exceeded the normal furnace temperature, and a drop of temperature was then recorded. This amounted to 2 degrees Cent. in curve 1 and 24 degrees Cent. in curve 2; the drop for curve 3, though not recorded, was very considerable.

In these austenitic steels the effect of rate of heating upon the temperature of Ac_t is much more pronounced than in the martensitic steels, though with slow rates the difference between the two types of steel is small, if any. Thus by comparison of curve 1 for the austenitic steel

(rate of heating, 0.08 degree Cent. per second) with the curve for the 0.95 per cent carbon steel (rate of heating, 0.16 degree Cent. per second), in both of which cases the rate is approximately the same at the maximum, one may note that the maximum for the austenitic steel is 23 degrees Cent. higher and the end only 11 degrees Cent. higher than for the martensitic steel, even though an actual temperature drop occurred in the former case. This would indicate that for very slow rates there would be little temperature difference between Ac_t for a martensitic

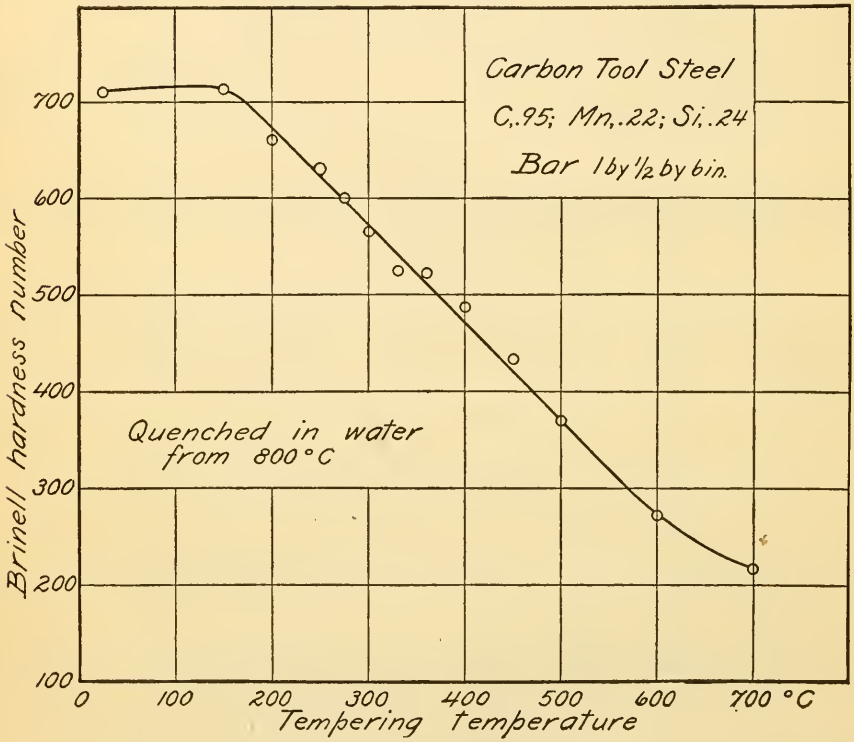

Fig. 9—Effect of tempering temperature on Brinell hardness of 0.95 per cent carbon steel

structure and Ac_t for an austenitic one. Here again the fact that the beginning for both is practically the same verifies the conclusion that the heat evolution of the transformation materially affects its observed temperature for sensible rates of heating.

Curve 4 of Fig. 5 shows the thermal characteristics of one of the austenitic steels after exposure for 30 minutes in liquid air. This treatment rendered the steel partially martensitic in structure as shown in Fig. 7*b*. Comparison of the heating curve 4 for this sample with curve 2, the rate of heating being essentially the same in both cases, shows that treatment in liquid air causes (1) a lowering of the maximum and end of the transformation by about 45 degrees Cent., and (2) an evolution of heat much less intense, without any recorded drop of temperature. This indicates a marked structural change, evidently from austenite to martensite, on immersion of the austenitic steel in liquid air.

Further examination of the heating curves of the austenitic steels reveals another significant phenomenon. An inflection in these curves may be noted at 273 degrees Cent. for curve 2, 285 degrees Cent. for curve 3, and somewhat lower for curve 1, at which temperature there is an augmentation of the rate of heating. It is evident from curves 2 and 4 that the heat evolution of the latter or martensitic steel starts to drop

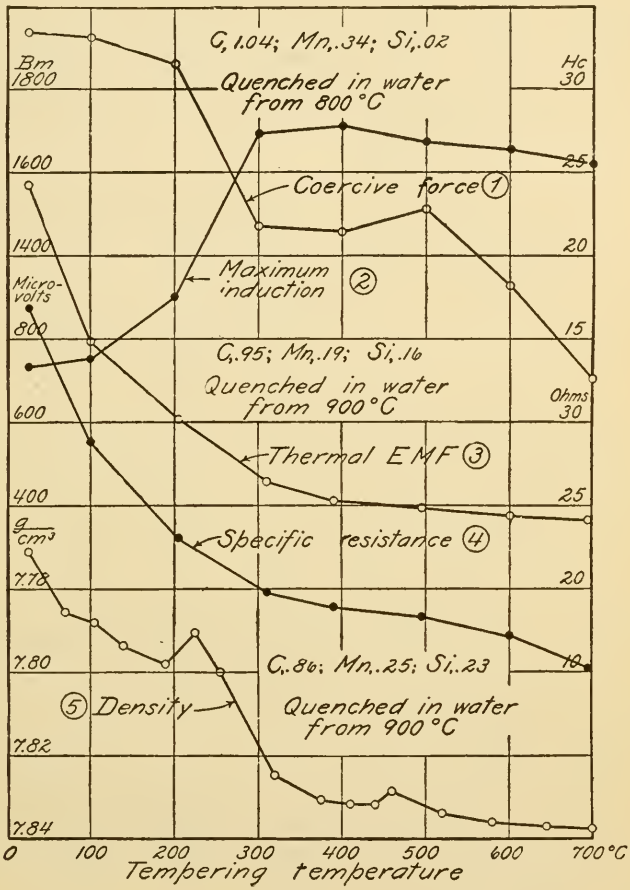

Fig. 10—Change of physical properties with tempering temperature of martensitic carbon steels

off, while the former or austenitic steel is considerably intensified just above the inflection temperature of 273 degrees Cent. This indicates two stages in the decomposition of the austenitic steel—namely, the low temperature stage, probably a manifestation of the simple carbide precipitation, and the high temperature stage, which is the same intensified by the A_3 and A_2 transformation. In the case of the martensitic steel the change designated by Ac_t is very probably due only to the carbide precipitation.

The thermal curves presented here show a rapidly increasing heat evolution (Ac_t) from 155 to 250 degrees Cent., ending abruptly at about

260 degrees Cent. for a very slow heating rate. This last temperature, 260 degrees Cent., very probably represents the completion of the change from martensite into troostite. A consideration of the changes in physical properties on tempering quenched steels through the Ac_t range should, therefore, assist materially in determining other characteristics of this change.

In order to make a reliable comparison of the characteristics of Ac_t with the changes in the standard scleroscope and Brinell hardness numbers, measurements were made on samples of the 0.95 per cent carbon steel used for the majority of the thermal curves. The results are shown in Figs. 8 and 9, the recording scleroscope being used in the first case and the usual Brinell equipment in the latter. A fresh surface of the ball was taken for every impression.[12]

For the purpose of comparing some of the other physical properties with the heat evolution, Fig. 10 was prepared. Curves 1 and 2 of this figure were obtained from the magnetic data of Burrows and Fahy[13] and are expressed in gausses per square centimenter; curves 3 and 4 were obtained from the electric resistance and thermal electromotive force data of Campbell,[14] and curve 5 was obtained from the density values of Schulz.[15] In all cases martensitic carbon steels were used of approximately the same carbon content as the 0.95 per cent carbon steel used here.

Upon returning to the hardness curves of Figs. 8 and 9 one may see that the scleroscope hardness does not drop off abruptly until slightly above the temperature 260 degrees Cent. of the end of Ac_t, and that the Brinell hardness begins to drop linearly immediately above the beginning of Ac_t. Thus there exists in both the hardness curves an inflection closely related to fundamental temperature characteristics of the heat evolution.

Consideration next of curves 1 and 2, Fig. 10, for coercive force and maximum induction, respectively, will show that these properties change with an increasing rate over the range 20 to 300 degrees Cent. in the same manner as the heat evolution. The tempering temperature steps were not taken sufficiently close to define the end point of this change, but it coincides substantially with the end of Ac_t. The curves 3 and 4, for thermal electromotive force against pure iron and specific resistance, respectively, are practically parallel and may, therefore, be considered as a unit. It may be observed that the change is about 85 per cent complete at 300 degrees Cent., or in the Ac_t range. The density curve 5 is somewhat irregular, but the maximum rate of change occurs in the vicinity of the end of Ac_t.

From the foregoing analysis it is evident that the changes in the physical properties considered are related very closely to the heat evolution Ac_t, particularly in the case of the magnetic properties, maximum induction, and coercive force. These relations are forceful indications of a natural boundary between martensite and the troostite produced at about 260 degrees Cent. on tempering. Such a boundary should be detectable also by the changes in microstructure. Authorities, however, differ on the temperature of this boundary for simple steels, and place

[12] Since these Brinell data were obtained, the work of Chevenard (see footnote 5) appeared, containing a curve for an 0.85 per cent C steel practically identical in form with Fig. 9, with the exception that his values are somewhat lower.

[13] Burrows and Fahy, Trans. A. S. T. M., 19, part II, p. 5; 1919.

[14] Campbell, J. Iron and Steel Inst., 94, p. 268; 1916.

[15] Schulz, Forschungsarbeiten, No. 161, p. 1; 1914.

it anywhere in the range from 250 degrees Cent. to 400 degrees Cent. Careful observers have studied this change, and while not suggesting an end point, have made observations indicative of one in the region of the end of Ac_t.

Howe and Levy,[16] after quenching eutectoid carbon steel from 1100 degrees Cent. to water, find that on a 5-minute exposure to 300 degrees Cent. the original white martensite needles are almost completely broken up. Heyn[17] notes a coarsening of the needle structure at 275 degrees Cent. These observations are indicative of a structural change in the vicinity of the end of the heat evolution. The region under investigation is thus narrowed down, and future observers should have little difficulty in defining precisely the nature of the accompanying changes.

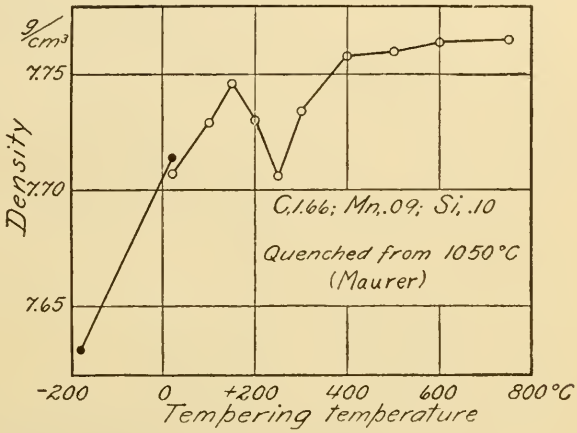

Fig. 11—Change in density with tempering temperature of semi-austenitic carbon steel (Maurer)

In foregoing paragraphs attention was called to a sharp change in direction of the heating curves of the austenitic steel. This inflection, denoting an abrupt increase in the rate of heat evolution, was noted to start at about the temperature at which the heat evolution in a martensitic steel begins to disappear. It may therefore be of some interest to compare this thermal behavior of the steel with the density changes in similar steel. In Fig. 11 are plotted density values given by Maurer[18] for a 1.66 per cent carbon steel quenched in water from 1.050 degrees Cent. The resulting structure is not completely austenitic, but nearly so. The curve shows three distinct regions: (1) 20 to 150 degrees Cent., in which the density increases as in a martensitic steel; (2) 150 to 250 degrees Cent., in which a drop occurs which recalls the second stage of the heat change of the austenitic steel; and (3) above 250 degrees Cent., in which it follows the normal course of a martensitic steel. Since martensitization implies a decrease in density (see the black circles of Fig. 11, representing the density change on immersion in liquid air), the second step with a density drop is evidently attributable to completion of the change from austenite to martensite, which is more or less transformed into

[16] Howe and Levy, Trans. A. S. T. M., 16, part II, p. 7; 1916.
[17] Heyn quoted by Sauveur, The Metallography and Heat Treatment of Steel, p. 304.
[18] See footnote 2.

troostite. The augmentation of the heat evolution of the austenitic steels, as previously explained, is therefore definitely verified.

In this paper the transformation, observed as an evolution of heat, on heating curves of hardened steel has been designated here as Ac_t, and its characteristics as revealed in carbon steels have been investigated. The effect of several variables was noted with the following conclusions:

1. An increase in the rate of heating raises markedly the temperature of Ac_t for a 0.95 per cent carbon martensitic steel and has a yet more marked effect for an austenitic carbon steel. For zero rate of heating there appears, however, to be little, if any, difference between the principal temperatures, whether the steel is of high or low carbon content or whether it is martensitic or austenitic. The principal temperatures for the 0.95 per cent carbon martensitic steel were found to be 155, 250, and 260 degrees Cent., respectively, for the beginning, maximum, and end.

2. The results obtained for specimens tempered at different temperatures before taking heating curves confirm substantially the temperature of the end of Ac_t just given.

3. Tempering for a short time at a temperature within the Ac_t range has an effect on the transformation characteristics similar to tempering for a longer time at a somewhat lower temperature.

4. The heat evolution of the austenitic steel takes place in two steps, the second being probably connected with the transition from austenite to martensite.

5. A survey of the changes in some physical properties of martensitic carbon steels through the tempering range leads to the conclusion that these changes are all directly related to the heat evolution observed, but only in the case of the magnetic properties, coercive force, and maximum induction is the change of the same type.

6. The change in density of a semiaustenitic carbon steel proceeds in steps similar to the heat evolution of the austenitic steel.

7. The changes in microstructure on tempering martensitic steels are unquestionably related to the heat evolution, but further study is necessary to establish fully this relation. The end point, 260 degrees Cent. for zero rate of Ac_t may very properly be taken as the natural boundary between martensite and the troostite of tempering, representing as it does the end of the transformation suppressed on rapid cooling.

NEW MEMBERS' ADDRESSES OF THE AMERICAN SOCIETY FOR STEEL TREATING

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PECK, CHARLES—from 544 Lincoln Way, E. South Bend, Ind. to 512 Fulton St., Elizabeth, N. J.

PLOURD, William H.—from 2911 S. Park Ave., Chicago, Ill. to Brookfield, Ill.
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News of the Chapters

A BIG year is planned by the Pittsburgh Chapter. On August 23, the council of the chapter met at a dinner at the Hotel Chatham for the purpose of discussing plans for the coming year. This council was made up of about 20, including the various officers and members of committees. Doctor Johnson, recently elected chairman of the chapter is ambitious to make it the biggest year the Pittsburgh chapter has ever known and accordingly has been holding various committee meetings to complete arrangements. It was decided that the entertainment committee should provide some special entertainment feature for each regular meeting. This feature will be in the nature of a surprise.

An unusually prominent and interesting group of speakers has been secured for the coming meetings, which will be held on the first Tuesday of each month. At the first meeting, Sept. 6, Professor MacIntosh of Carnegie Institute of Technology will speak on "The Metallurgy of Iron and Steel." This meeting will be in the Hotel Chatham and will be preceded by a dinner at 6:30 and the special entertainment feature mentioned above. The October meeting will be addressed by Charles E. Carpenter,

president of the E. F. Houghton Co. a speaker who is nationally known. His subject will be "Individualism vs Socialism. In November, Prof. Albert Sauveur of Harvard University, will speak on the "Heat Treatment of Steel." In December Prof. H. F. Moore of the University of Illinois will discuss "Fatigue Testing and Resistance of Materials." Col. A. E. White of the University of Michigan will discuss "Alloy Steel" at the January meeting. Other speakers of prominence who will address the chapter at later dates are: Prof. F. M. Crabtree of the Carnegie Institute of Technology; Prof. S. L. Goodale of the University of Pittsburgh; Dr. J. S. Unger of the Carnegie Steel Co. and Frank P. Gilligan of the Southern Engineering Co. and president elect of the National Society.

At the meeting delegates were appointed to the National Convention in Indianapolis, September 19 to 24 and instructed to bring the 1922 convention to Pittsburgh.

Commercial Items of Interest

AN INTENSIVE night course in metallography for heat treaters, chemists and laboratory assistants is to be conducted by the Cleveland School of Technology sponsored by the Central Young Men's Christian Association. C. G. Shontz, metallurgist of the Perfection Spring Co., Cleveland and secretary of the Cleveland Chapter of the American Society for Steel Treating will be the instructor. Classes will be held two and one-half hours on two evenings of each week for a period of 16 weeks. The outline of the course includes: Physical tests and their value; iron and steel; pure iron; wrought iron and low carbon steel; medium and high carbon steel; impurities in steel; mechanical treatment of steel; pyrometers and thermal critical points; iron—carbon diagram; cast steel; annealing of steel; hardening and tempering; cementation and case hardening; alloy steels; cast iron and malleable iron; and defects and failures.

The Case Hardening of Steel by Harry Brearley is the title of a 208-page book published recently by Longmans, Green & Co., New York. By way of review *The Iron Trade Review* says:

"Changes in structure and properties induced in steel by cementation and allied processes is the subject treated by this book which is made complete by the use of many illustrations. Since the material was developed mainly for the use of those actively engaged or interested in the commercial manufacture of case hardened products, the chapters are arranged to appeal to the workshop experience of the workmen.

"In preparation of the book, effort has been made to explain the microphotographs in as simple terms as possible. The author points out that an explanation based on the mechanical structure of an object is intelligible, because most minds can appreciate the elements of design and pass judgment on the composite properties of the materials. For that reason numerous microphotographs are used, and for the same reason, the writer states, the assistance offered by microscopic methods,

whatever the means of magnification are available, should not be ignored in workshop practice.

"The first edition of the book was published in 1914 but has been out of print for some time. As a result of the war and advances in heat treatment made by the urgent demands for steel, many changes have occurred. In preparing the second edition, therefore, the author has included the most recent revisions in metallurgical practice."

H. B. Knowlton, consulting metallurgist of the Case Hardening Service Co., Cleveland, manufacturers of case hardening material is taking a post graduate course in the department of metallurgy at Columbia university.

To show his appreciation of the honor conferred upon him by the presentation of the John Fritz Medal, Sir Robert A. Hadfield of London, Eng., has published an elaborate 42-page booklet containing his address of thanks made before the Institution of Civil Engineers. The booklet shows the photographs of previous recipients of the medal together with a history of the awards. Sir Robert briefly outlines his discovery of and research with manganese steel in which connection the medal was awarded.

A new line of electric furnaces, added to the products of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., is described and illustrated in a 24-page illustrated booklet recently published by that company. The new type of furnace includes the multiple unit designed for use with heats of 1800 to 2000 degrees Fahr. According to the booklet the small heavy-duty furnaces of the multiple crucible type may be operated continuously at 2000 degrees Fahr. In the booklet heavy-duty industrial furnaces with appliances for annealing, hardening, drawing and enameling are described in detail and in addition a discussion of the characteristics of these furnaces is given.

The agency arrangement for the sale of sheet steel heretofore existing between Thos. Firth & Sons, Ltd., of Sheffield, and Wheelock Lovejoy & Co. of New York and Cambridge, has been terminated, and Thos. Firth & Sons have appointed as their general sales manager for the United States Horace G. Hides of Hartford, Conn., who has for the past 20 years represented Wm. Jessop & Sons. The stock of Firth Sheffield sheets will be carried in the warehouse of an associate company the Firth-Sterling Steel Co., 312 Hudson street, New York. Thos. Firth & Sons and the Firth-Sterling Steel Co. are also opening a joint office in Hartford, Conn., where Mr. Hides will have his headquarters and where Henry I. Moore will represent the Firth-Sterling Steel Co.

Historical sketches of the discovery and the subsequent development of vanadium steel together with a description of the uses of steel containing this alloy are given in a booklet recently issued by the Vanadium Corp. of America, New York. According to the text, 90 per cent of the vanadium produced comes from deposits at Cero de Pasco, Peru.

The major portion of the booklet is devoted to a description of the products which are manufactured from vanadium-alloy steel. Some of these commodities are airplane fittings and engine parts, cast iron shell forging tools, torpedo air flasks, armor plate, steel helmets, submarine

crankshafts, caterpillar mounts for naval guns, valve gears, locomotive parts, large castings for cores and shafts, roller bearings, automobiles and tucks, springs, tool steel, piston rods, and air compressors. Charts in the last pages of the publication show the physical properties at different drawback temperatures. The booklet contains 50 pages and is illustrated throughout.

The General Alloys Co., New York, announces that it has developed a new heat resisting alloy which will be marketed at an unusually low base price. This alloy, it is said, has about four times the life of steel and has the additional advantage of retaining its shape at high temperature. It is covered by a basic principle recently issued. The new metal is a development of 11 years research and experiment. Over 30 tons of experimental castings were made and tested before the material was placed on the market.

Anthracite coal and its production will be the principal subject for discussion at the semicentennial anniversary meeting of the American Institute of Mining and Metallurgical Engineers to be held at Wilkes-Barre, Pa., Sept. 12-15. At the metal section, which will convene Monday night, the following papers will be presented: "Application in Rolling of Effects of Carbon, Phosphorus and Manganese on Mechanical Properties of Steel" by W. R. Webster; "Thacher Process for Molding and Casting Propeller Blades and Wheels" by E. Touceda; and "Making a 5 Per Cent Nickel-Cast Iron Alloy in an Electric Furnace," by D. N. Whitman.

The George J. Hagan Co., Pittsburgh, Pa., has just completed the erection of a modern steel factory building adjacent to its foundry at Orrville, O. This building is to be used for construction and development work on all types of furnaces and furnace equipment .

E. S. Crosby, sales and advertising manager for the United States and Cuban Allied Works Engineering Corp., has resigned to become manager of the eastern district of the Celite Products Co., producers of an insulating material and a filtering medium. Previous to his service in France with the army, he was assistant sales manager for the De-Laval Steam Turbine Co., Trenton, N. J. Mr. Crosby will make his headquarters at 11 Broadway, New York.

Ralph C. Schwarz has taken over the northwestern New York territory for the distribution and sale of industrial furnaces and appliances manufactued by the Chicago Flexible Shaft Co., Chicago. Mr. Schwarz's address will be 921 Granite building, Rochester, N. Y.

"Furnaces for the Heat Treatment of Metals" is the title of an 8-page catalog issued recently by the Barkling Fuel Engineering Co., 1743 N. Kenton avenue, Chicago. Four of the furnaces described are an oven furnace for hardening high speed and carbon steels; an oven furnace for heat treating, carbonizing and annealing; a forging furnace for drop hammer; and bull dozer work; an annealing, tool and die

(*Concluded on Page* 36)

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TRANSACTIONS
of the
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Vol. 1 Cleveland, February, 1921 No. 5

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WILSON, A. J. (Member), Foreman Heat Treat., Warner Gear Co., Muncie, Ind.

WILSON, Chas. H. (Associate), President, Wilson-Maeulen Company, 383 Concord Ave., New York City, and *for mail,* 65 South 2nd Ave., Mt. Vernon, New York.

WILSON, G. F. (Sustaining), Dist. Mgr., Ludlum Steel Company, 816 Mercantile Library Bldg., Cincinnati, O.

WILSON, James A. (Member), President, Brooklyn Steel Treating Corporation, 8-10 Franklin St., Brooklyn, New York.

WILSON, Robert R. (Member), Foreman, Century Steel Company of America, Poughkeepsie, New York.

WILSON, Wayne W. (Member), Metallurgist, Union Drawn Steel Co., 69 Jos. Campan, Detroit, Mich.

WILSON, Wm. W. (Member), V. P. & Gen. Mgr., Wilson & Williard Mfg. Co., and *for mail,* 2214 Fourth Ave., Los Angeles, Calif.

WILLARD, C. T. (Member), Singer Mfg. Co., Elizabethport, N. J.

WILLETT, G. H. (Associate), Pres. & Gen. Mgr., Standard Fuel Eng. Co., Detroit, and *for mail,* 1778 W. Grand Blvd., Detroit, Mich.

WILLIAMS, Alfred O. (Member), 417 Front St., Buchanan, Mich.

WILLIAMS, Edw. (Member), Chemist, Nat. Brake Elec. Co., Bellview Place, Milwaukee, Wis., and *for mail,* 812 41st St., Milwaukee, Wis.

WILLIAMS, Dean R. (Associate), 2024 Garfield Ave. So., Minneapolis, Minn.

WILLIAMS, G. A. (Member), 900 East 146th St., Cleveland, O.

WILLIAMS, H. M. (Member), Research Engr., Gen. Motors Research Corp., Box 745, Dayton, O.

WILLIAMS, Louis W. (Member), Mgr. Union Drawn Steel Co., 460 Washington St., New York City.

WILLIAMS, R. L. (Associate), Dist. Mgr., Crucible Steel Co. of Am., 473 Lafayette Blvd., Detroit, Mich.

WILLIAMS, R. W. (Member), Sheldon Axle & Spring Co., Wilkes Barre, Pa.

WILLIAMS, Reginald W. (Member), Messrs. Sidney Williams & Co., Sydney, N. S. W., Australia.

WILLIAMS, William (Member), 4133 Camelia Ave., St. Louis, Mo.

WILLIAMS, W. E. (Associate), Cataract Refining Company, 735 Webster Building, Chicago, Ill.

WILLS, Wm. H. (Member), Metallurgist, Braeburn Steel Company, Braeburn, Pa.

WILLSE, C. O. (Member), 1844 N. 27th St., Philadelphia, Pa.

WILLSON, Edwin L. (Associate), Treasurer, Connecticut Electric Steel Co., Hartford, Conn., and *for mail,* 540 Flatbush Ave., Hartford, Conn.

WINEMAN, Chas. (Member), 651 Waterman Ave., Detroit, Mich.

WINGERT, G. H. (Member), Heat Treater, Adams Axle Co., Findlay, O.

WINKLER, Carl J. (Member), Supt., Automatic Parts Co., Indianapolis, Ind.

WINSLOW, Ralph H. (Member), Tool Rm. Foreman, Van Sicklem Speed. Co., Toledo, and *for mail,* 442 Cumberland Place, Toledo, O.

WINTER, Chas. F. (Member), Insp. Foreman, Goodman Manufacturing Co., 1150 East 62nd St., Chicago, Ill.

WINTERSTEIN, C. C. (Associate), Salesman, U. S. Gas Improvement Co., 315 Arch St., Philadelphia, Pa.

WIRFS, R. A. (Associate), Pres., Roland A. Wirfs Co., Odd Fellows Bldg., St. Louis, Mo.

WIRRER, Godfrey (Member), M. E., International Motor Co., Plainfield, N. J., and *for mail,* 38 Compton Ave., Plainfield, N. J.

WIRRY, Albert (Member), Supt., Walker Mfg. Co., Racine, Wis.

WISE, Clarence E. (Member), Cruc. Steel Co. of A., La Belle Works, Pittsburgh, Pa.

WISTRAND, Erik O. (Member), 1104 18th Ave. NE., Minneapolis, Minn.

WITTER, A. E. (Member), Secy.-Gen. Mgr., Mansfield Lock Washer Co., Mansfield, O.

WITTERSHEIM, J. H. (Member), Doreman Heat Treat., Henry Ford & Sons, Dearborn, Mich., and *for mail,* Box 50, Dearborn, Mich.

WOHLERS, Henry (Member), Box 1658, Springfield, Mass.

WOLF, John (Member), Heat Treating Department, 1941 Park Ave., Chicago, Ill.

WOLLENSAK, Arthur C. (Member), Ch. Engr., Sterling Motor Truck Co., Milwaukee, Wis.

(Continued on Page 64 Advertising Section)

EMPLOYMENT SERVICE BUREAU

The employment service bureau is free to all members of the Society. If you wish a position, your want ad will be printed free in two issues of the Transactions.

This service is also free to employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published free in two issues of the Transactions.

Important Notice.

In addressing answers to advertisements on these pages, a stamped envelop containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS OPEN

WANTED—Man to take charge of hardening room in gear manufacturing plant located in large city in Texas. Position permanent to right party. Answer PO-4

POSITION OPEN—for a steel salesman for Illinois and Iowa. Desire man acquainted with trade in Tri-Cities. Man with practical shop and hardening experience preferred. Permanent position to right man with opportunity for advancement. Salary to start $175.00 and bonus. Answer PO-2

POSITION OPEN—Want to get in touch with a few established manufacturers, agents or high calibered district salesmen to sell the best heat resisting alloys obtainable. We are making some changes in an established organization. Answer PO-3

POSITION OPEN—for thoroughly experienced metallurgist to take charge of heat treating department and all its branches, with one of largest manufacturers of farm implements in the country. Answer PO-5

WANTED SUPERINTENDENT—First class pyrometer man, capable of handling installations service work, pyrometer maintenance, and instrument repairs. Answer PO-6

WANTED—In tool and alloy steel research department, 1919-1920 technical graduate, who has specialized in iron and steel metallurgy. Must not be afraid of getting right down to brass tacks in the way of running experimental melting and heat treating furnaces. Duties include wide range of work, and position offers unusual opportunity for future advancement. Address P. O.-7

POSITIONS WANTED

WANTED—Position as sales manager, Gentile of years of experience in tools, tool and alloy steels with unquestionable references in every respect, including many very desirable accounts, thoroughly acquainted with Middle West trade, capable of organizing and handling either main of district office, open to negotitate. Answer 1-33

WANTED—Position as chemist or metallurgist. Seven years experience in carbon and alloy steels. Thoroughly experienced in laboratory research, testing, and shop problems concerning steel. References. Answer 1-34

WANTED—Position as chief or assistant metallurgist. Graduate of University of Michigan. Five years' experience with largest motor car manufacturing companies. Salary $3600.00 Answer 1-5

WANTED—Position as metallurgist. College training. Qualified to direct chemical laboratories. Thoroughly experienced in modern physical test methods, pyrometers, foundry and plant control. A-1 references. Michigan territory desired. Answer

WANTED—Metallurgical position. College graduate in metallurgy. 26 years old. Has been employed with large steel concern having control of pyrometers. Has also done metallographic work. Answer 1-7

WANTED—Position as metallurgist. Capable of directing heat treating department and chemical laboratory. 8 years' experience in forging and steel stamping field. Answer 1-18

WANTED—Position as metallurgist in New England territory. Married. College graduate. Extensive experience in analysis and testing carbon and alloy steels in automobile and aircraft plants, also industrial research. Salary $60.00 a week. Answer 1-9.

WANTED—Position as foreman of heat treating plant. 37 years old. Married. Valuable experience. Best references. Detroit territory preferred. Answer 1-10

WANTED—Position in vocational shop training or foreman of production department. Graduate of University of Missouri. Extensive experience. A-1 references. Missouri or Illinios locality preferred. Answer 1-11

WANTED—Position as foreman of heat treating department. 5 years' in charge of large automobile company's plant. Best of references. Detroit territory preferred. Answer 1-12

WANTED—Position as metallurgist in Chicago or vicinity. Married. 30 years old. 3 years in Chicago Technical College. 6 years' practical experience. Salary $3000.00. Answer 1-14

POSITION WANTED—As metallurgical engineer in technical or executive capacity. Six years experience in the automotive industry with few well known concerns. Experienced in physical and chemical testing, metallography, design of modern heat treating plants and control. Technical graduate. Married. Age 29. Answer 1-15

WANTED—Position as steel salesman. Has large trade in New England states who are users of high speed as well as carbon steels. Is thoroughly experienced man and capable of making demonstrations. Trade consists of some of largest machine companies in East. Can furnish best references as to ability as salesman and as to character. Answer 1-16

WANTED—Graduate engineer at present employed as assistant to metallurgist in one of largest tractor companies in United States is open for position as assistant metallurgist, heat treating superintendent, supervisor of physical tests, chief chemist. Four years experience. Answer 1-17

WANTED—Position as foreman of heat treating or blacksmith shop. High School graduate. Married. Specialized in heat treating for 10 years. Valuable experience. Best of references. Answer 1-22

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